Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 111 No. 2 (2010) 119-127

urn:nbn:de:hebis:34-2011072538416 ISSN: 1612-9830 – journal online: www.jarts.info

Using a Double-pass solar drier for drying of bamboo shoots

Jan Banout*, Petr Ehl

Department of Sustainable Technologies, Czech University of Life Sciences Prague, Czech Republic

Abstract

Three different drying methods, a forced convection double-pass solar drier (DPSD), typical cabinet type natural convection solar drier (CD) and traditional open-sun drying (OSD) were used for draying of bamboo shoots in central Vietnam. During drying the operational parameters such as drying temperature, relative humidity, air velocity, insolation and water evaporation have been recorded hourly. The mean drying temperatures and relative humidity in the drying chamber were 55.2°C, 23.7 %; 47.5°C, 37,6 %; 36.2°C, 47.8 % in DPSD, CD and OSD, respectively. The mean global radiation during all experimental runs was 670 W m^{-2}. The result also shows that fastest drying process was occurred in DPSD where the falling-rate period was achieved after 7 hours, in change to OSD where it took 16 hours. The overall drying efficiency was 23.11 %, 15.83 % and 9.73 % in case of DPSD, CD and OSD, respectively. Although the construction cost of DPSD was significantly higher than in CD, the drying costs per one kilogram of bamboo shoots were by 42.8 % lower in case of DPSD as compared to CD. Double-pass solar drier was found to be technically and economically suitable for drying of bamboo shoots under the specific conditions in central Vietnam and in all cases, the use of this drier led to considerable reduction in drying time in comparison to traditional open-sun drying.

Keywords: solar drying, drying efficiency, drying rate, bamboo shoots, central Vietnam

Abbreviations:
DPSD – Double-pass solar drier
CD – typical cabinet-type natural convection solar drier
OSD – traditional open-air sun drying
w.b. – wet basis
d.b. – dry basis

1 Introduction

Bamboos play an important role in daily life of rural people in numerous ways, from house construction, agricultural implements to provide food (Satya *et al.*, 2010). Spring bamboo shoots are a popular and highly priced vegetable grown widely in most Southeast Asian countries such as China, Philippines, Thailand and Vietnam. Bamboo shoot contains about 88.8 % water, more than 3.9 % protein and 17 amino acids. Amino acid content of bamboo shoot is much higher than found in other vegetables such as cabbage, carrot, onion and pumpkin. They also provide carbohydrates and vitamins essential for human nutrition (Satya *et al.*, 2010; Xu *et al.*, 2005). Fresh bamboo shoots are not easily stored as they rapidly turn brown during storage. Therefore, drying is one of possible preservation method which can prolong the shelf-life of fresh bamboo shoots and helps to provide the consumer with the product throughout the year.

Drying is an old means of food preservation of the excess production and uses the energy from the sun until the development of mechanical dryers. Open-air sun drying requires little investment, but causes significant losses due to product humidity reabsorption during inadequate climatic conditions; contamination by pathogens, rodents, birds and insects; as well as by inorganic trash materials such as dust, sand etc. Conversely the artificial driers produce an improved quality of dried products as the velocity and the temperature of the drying air can be controlled, but they also consume a significant amount of energy to heat and move the airflow (Janjai *et al.*, 2009; Ferreira *et al.*, 2008) resulting in higher capital and operational costs of those driers. An alternative to traditional open-air sun drying is the use of solar driers especially because of lower investments

*Corresponding author
Department of Sustainable Technologies, Czech University of Life Sciences Prague, Kamycka 129 165 21 Prague 6-Suchdol, Czech Republic
Email: banout@its.czu.cz

comparing to sophisticated drying techniques using fossil fuels and because of the fact that most developing countries are situated in climatic zones where the insolation is considerably higher than the world average of 3.82 kWh m^{-2} a day (Imre, 2007). Advantages of solar driers that enable them to compete with traditional open-air sun drying techniques and/or artificial driers powered by energy from fossil fuels have been previously reported in the literature by many researchers (Murthy, 2009; Hossain & Bala, 2007; Karathanos & Belessiotis, 1997). Solar driers are usually classified according to the mode of airflow as natural and forced convection driers. Natural convection driers do not require fans to pump the air through the drier (Forson *et al.*, 2007). They are low-cost, can be locally constructed and do not require energy from fossil fuels (Sharma, 1995). However, some drying limitations because of lower buoyancy of natural convection solar driers in comparison with forced convection ones may be expected. Jain & Tiwari (2004) reported that the convective mass transfer coefficient in greenhouse drying under forced mode is double that of natural convection in the initial stage of drying. According to a survey conducted in several countries in Asia-Pacific region, the best potential and popular solar driers are: (i) natural convection cabinet type, (ii) forced convection indirect type and (iii) green house type (Murthy, 2009).

Thus, the main objective of this study was to compare a forced convection indirect type solar drier called Double-pass solar drier with typical cabinet solar drier and traditional open-air sun drying technique in central Vietnam for bamboo shoots drying. Mainly the drying performance and economic aspects of drying have been investigated in this study.

2 Materials and Methods

2.1 Sample preparation

Fresh bamboo shoots were purchased at the local vegetable market in Hue City, Vietnam. For each experimental run (drying in DPSD, cabinet drier and open-air sun drying) a 49 kg of fresh bamboo shoots were used. Fresh bamboo shoots were stored before each experimental run at 5°C and used within 1 to 2 days of purchase. Before drying the bamboo shoots were washed by potable water and placed on plastic trays to drain out excess water. Then the bamboo shoots were cut to 0.3 cm thick and 5 cm × 4 cm (width × length) slices. The drying was occurred without any pretreatments.

2.2 Experimental procedure

Two different types of solar driers together with open-air sun drying were used for the present investigation: (i) a forced convection Double-pass solar drier (Fig. 1) developed and designed at Institute of tropics and subtropics, Czech University of Life Sciences Prague and previously described by Banout *et al.* (2011); (ii) a typical cabinet-type natural convection solar drier as described by Sharma (1995) and Ekechukwu & Norton (1999) with floor area 0.65 m × 1.5 m and 0.6 m one side height and 0.3 m second side height, (iii) a black plastic sheet 2 m × 2 m (width × length) was used as traditional open-air sun drying method.

All drying facilities were established at Hue University of Agriculture and forestry, Hue city, central Vietnam (16° 28' 36.46" N, 107° 34' 23.78" E). A total of three full scale experimental sets of bamboo shoots drying were conducted from July 2009 to September 2009. Each drying test started after completion of the loading, usually at 8 a.m. and discontinued at 4 p.m. All drying units were loaded at maximum capacity during all experiments, which corresponding to loading density 4.25 kg m^{-2}, 3.30 kg m^{-2}, 3.06 kg m^{-2} for DPSD, CD and OSD, respectively. Following operational parameters were measured every hour during solar drying experiments: ambient air temperature (°C); ambient air relative humidity (%); inlet and outlet drying air temperature (°C); inlet and outlet drying air relative humidity (%); drying airflow rate ($m^3 h^{-1}$); drying air velocity ($m s^{-1}$); and global solar radiation ($W m^{-2}$). To compare the performance of DPSD with CD and OSD three control samples of bamboo shoots were weighed and placed on well-marked areas on the trays in each drying unit. Weight loss of control samples (g) in the DPSD, CD and OSD were measured during the drying period at one hour intervals as well. At the end of each drying test all control samples were collected and placed to the laboratory electric oven for 24 h at 105°C to estimate dry matter content.

2.3 Instrumentation

A thermometer-hygrometer S3121 (Comet System, Czech Republic; accuracy ± 0.4°C ± 2.5 % relative humidity [RH] between 5 % and 95 %) with external temperature and RH probe was used to measure the ambient air relative humidity and temperature, drying air temperature and relative humidity inside the drying chambers. The drying airflow rate and the drying air velocity were measured with anemometer Testo 425 (Lenzkirch, Germany) with accuracy ± 0.03 m s^{-1}. In case of Double-pass solar drier the drying air temperature, drying air relative humidity and drying air velocity were measured at the inlet and outlet of the collector part and drying chamber as well. A pyranometer CMP 6 along with a solar integrator (Kipp Zonen, Delft, the Netherlands) with daily accuracy ± 5 % was applied to measure the global solar radiation incident on the collectors of the drier. A top loading digital balance (SOHENLE 2873; Soehnle Professional, Germany) with precision 0.1 g,

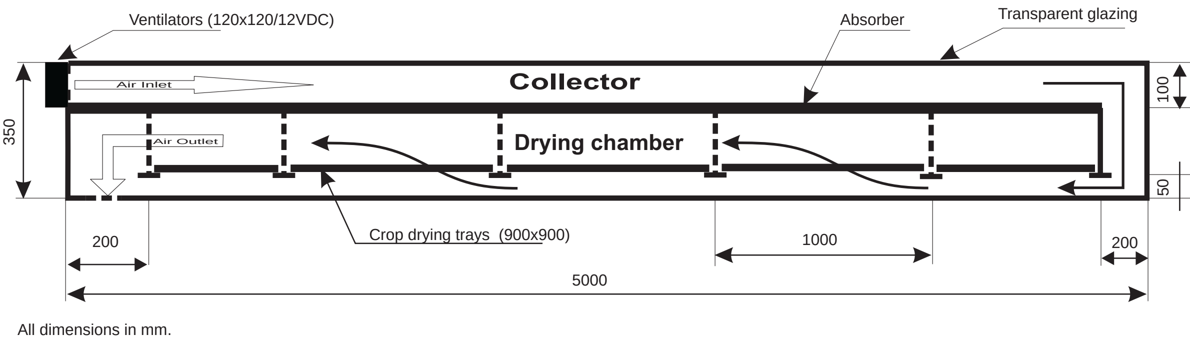

Fig. 1: *Description of Double-pass Solar Drier*

was used to weigh the control samples at hourly intervals during drying. The difference in weight between two consecutive hourly readings directly gave the amount of moisture evaporated during the observed time interval. The final moisture content of dried bamboo shoots was determined after drying in electric oven (UFE 500 type; Memmert, Germany) at 105°C for 24 h.

2.4 Performance and data analyses

The drying rate (*DR*) of bamboo shoots was evaluated by differentiating the polynomial equations with respect to time as decribed by Walde *et al.* (2006).

$$DR = \frac{-dM}{dt} \quad (1)$$

where M is the moisture content at any time (t) per unit weight of dry matter. To evaluate drying performance of both solar driers and open-air sun drying the overall system drying efficiency (ηd), first day drying efficiency (ηd_1), heat collection efficiency (ηc) and pick-up efficiency (ηp) were calculated during this study. The system efficiency of a solar drier is a measure of how effectively the input energy to the drying system is used in drying product. For natural convection solar driers the overall system efficiency can be calculated by Eq. (2):

$$\eta d = \frac{W\,\Delta Hl}{I\,A\,t} \quad (2)$$

where W is mass of evaporated water from the product (kg) in time t, ΔHl is latent heat of evaporation of water (kJ kg^{-1}), I is solar radiation on the aperture surface (W m^{-2}), A is aperture area of the drier (m^2) and t is time of drying (s).

System efficiency for the forced convection solar driers needs to take into account the energy consumed by the fan (Leon *et al.*, 2002). The following Eq. (3) is then used:

$$\eta d = \frac{W\,\Delta Hl}{I\,A\,t + Pf} \quad (3)$$

where Pf is energy consumption of fans (kWh).

Drying efficiency varies significantly with the moisture content of the product. For the same energy input, drying efficiency decreases when the drying process moves from constant-rate period to falling-rate period. Efficiency calculation during the constant-rate period could offer a more consistent evaluation of the drier thermal performance. However, due to the difficulty in observing the change from constant-rate period to falling-rate period with products having a definite constant-rate drying period, system efficiency during the first day of drying may be reasonably taken as a consistent measure of the thermal performance of the drier (Leon *et al.*, 2002). The first day drying efficiency (ηd_1) can be expressed by following Eq. (4):

$$\eta d_1 = \frac{W_1\,\Delta Hl}{I\,A\,t_1} \quad (4)$$

where W_1 is a mass of evaporated water from the product (kg) during first day and t_1 is time of drying during a first day (s). A measure of collector performance is the collector efficiency or heat collection efficiency, defined as the ratio of useful heat gain over any time period to the incident solar radiation over the same period (Koyuncu, 2006), thus we can define collection efficiency as:

$$\eta c = \frac{Qu}{I\,Ac} \quad (5)$$

where Qu is useful energy gain (W) and Ac is collector solar energy collection area (m^2). The useful heat gain by a collector can be expressed as:

$$Qu = V\,Cp(To\text{–}Ti) \quad (6)$$

where V is air flow rate (kg s^{-1} or m^3 s^{-1}), Cp is constant pressure specific heat (J kg^{-1}K^{-1}), To is outlet temperature (°C) and Ti is inlet temperature (°C). From Eqs. (5) and (6),

$$\eta c = \frac{V\,Cp(To\text{–}Ti)}{I\,Ac} \quad (7)$$

Pick-up efficiency is useful for evaluating the actual evaporation of moisture from the product inside the drier. It is a direct measure of how efficiently the capacity of air to absorb moisture is used. The pick-up efficiency is defined as the ratio of the moisture picked up by the air in the drying chamber to the theoretical capacity of the air to absorb moisture. Mathematically it can be expressed by Eq. (8).

$$\eta p = \frac{h_o - h_i}{h_{as} - h_i} = \frac{M_w}{\rho \, V_t \, (h_{as} - h_i)} \quad (8)$$

where h_o is absolute humidity of air leaving the drying chamber (%), h_i is absolute humidity of air entering the drying chamber (%), h_{as} is absolute humidity of the air entering the drier at the point of adiabatic saturation (%), M_w is mass of evaporated water from the product (kg) and ρ is density of air (kg m^{-3}).

2.5 Cost analysis

From the economic evaluation the traditional open-air sun drying (OSD) method was excluded because of irrelevancy. The drier cost is calculated as a sum of costs of used construction materials including labor expenses. The drying cost (Cd) is estimated as the ratio of annual cost (Ca) to the quantity of dried product per annum (Qg) as shown in Eq. (9).

$$Cd = \frac{Ca}{Qg} \quad (9)$$

The annual costs are calculated using Eq. (10) proposed by Simate (2003):

$$Ca = \left(C_T + \sum_{i=1}^{L} m_i \, \omega^i \right) \frac{\omega - 1}{\omega \, (\omega^L - 1)} \quad (10)$$

where C_T is drier cost (U.S. $), L is solar drier life (years), mi are maintenance costs in the i-th year (U.S. $) and ω is (100 + inflation rate (%)) / (100 + interest rate (%)). Maintenance costs were assumed to be 2 % of the total drier cost and solar drier life was 5 and 10 years for CD and DPSD, respectively. This is due to higher quality of construction materials used in case of DPSD. The quantity of dried product per annum is calculated from the throughput of the drier per hour (Qh) and the number of operating hours in a year (Dh) and is given by Eq. (11):

$$Qg = Qh \, Dh \quad (11)$$

According to the data from a local weather station of Thua Thien Hue province the average annual number of sunny hours in Hue city is 1846. This value was considered as a number of operating hours per year in Eq. (11). Economic evaluation of solar driers usually aims at determining the payback period. The dynamic method of calculations takes the influence of inflation and interest rates into consideration. Following Eq. (12) proposed by Singh *et al.* (2006) was used to calculate the payback period (N).

$$N = \frac{\ln\left(1 - \frac{C_T}{S}(d - f)\right)}{\ln\left(\frac{1+f}{1+d}\right)} \quad (12)$$

Where S are annual savings of solar drier (U.S. $), d is rate of interest and f is rate of inflation.

2.6 Statistical analysis

Effect of drying method on the relationship between drying rate and the moisture content was statistically evaluated using Statistica software version 8.0 (StatSoft Inc.Oklahoma, USA).

3 Results and Discussion

3.1 Drier performance

A mean values of drying air temperature and drying air relative humidity with corresponding solar radiation in DPSD, CD and OSD as recorded during a typical experimental run are presented in Fig. 2. and Fig. 3., respectively. From Fig. 2. is evident that in case of DPSD, it is possible to achieve highest mean drying temperatures around 54 °C while the mean drying temperatures in CD were around 47.5 °C and in case of OSD the drying temperatures are equal to ambient temperatures around 36 °C. Conversely Fig. 3. shows lower mean relative humidity of drying air around 23 % in case of DPSD while the mean relative humidity of drying air in case of CD and OSD were 36 % and 48 %, respectively.

From Fig. 2. and 3. it is also clear that in case of solar dryers DPSD and CD the maximum drying temperatures corresponds to maximum solar radiation and minimum drying air relative humidity. Measured mean drying temperatures in DPSD are in the recommended range of drying temperatures (50 to 65 °C) for drying of sensitive products such as fruits and vegetables (Sharma *et al.*, 2009).

All measured and calculated parameters for performance evaluation of DPSD compared to typical CD and traditional OSD are summarized in Table 1. The evaluation sheet presented in Table 1 was adopted from Leon *et al.* (2002) and slightly modified for the purposes of this study. From Table 1, it is evident that best drying efficiencies were achieved in case of DPSD.

The overall drying efficiency of DPSD is in the range of 20-30 % which is typical for forced convection solar driers (Purohit *et al.*, 2006). The first day drying efficiency was about 9 % higher in case of DPSD comparing to CD and about 11.3 % higher comparing to the OSD. In the study conducted by Hachemi (1997) it was concluded that the collection efficiency ranges from 49 to 75 % depending on the collector type and obstacles used in the collector. It was mentioned that fins significantly increase the collector efficiency. In this study the fins were used in the collector part of DPSD and from Table 1 it is evident that obtained collection efficiency has reached above mentioned values.

Focusing on the pick-up efficiency the results shows that during bamboo shoots drying the DPSD has about

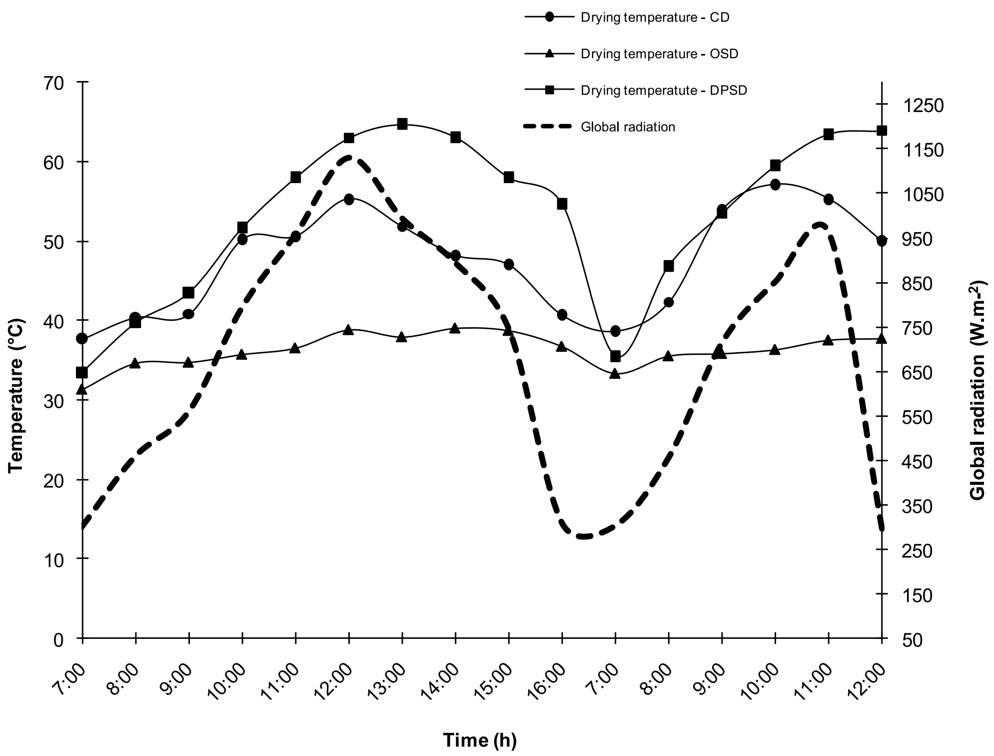

Fig. 2: *Variations of drying air temperatures and global solar radiation for typical drying test.*

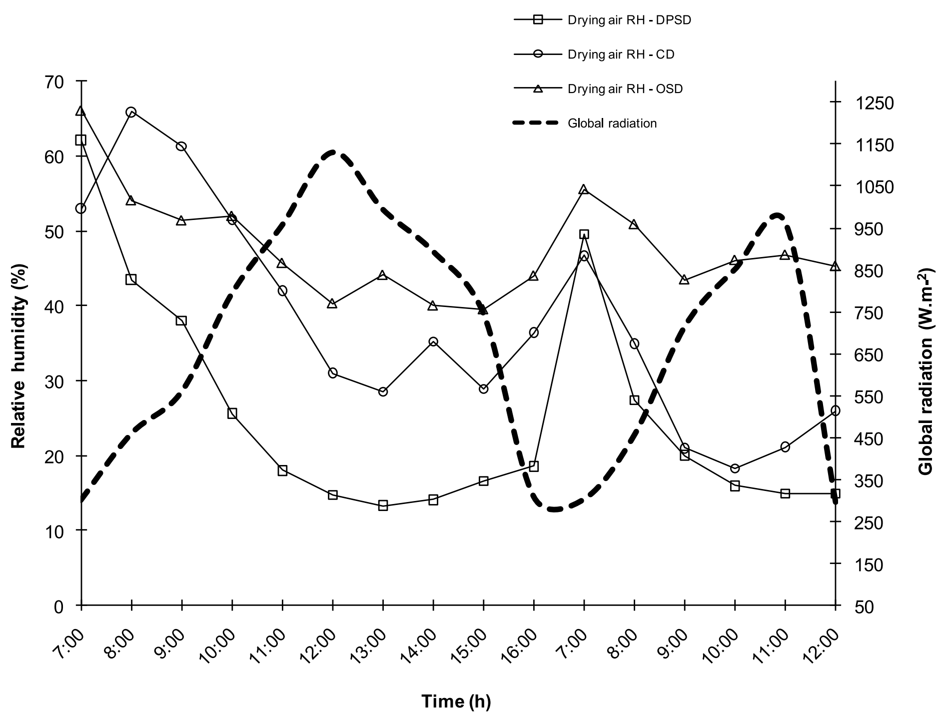

Fig. 3: *Variations of drying air relative humidity and global solar radiation for typical drying test.*

Table 1: *Performance evaluation of DPSD compared to CD and OSD*

	Day 1	Day2
Global radiation on the plane of solar collector (MJ/m^2)	23.15	20.70
Average ambient temperature (°C)	36.39	36.02
Average ambient relative humidity (%)	47.72	48.03

Product: Bamboo shoots; Initial moisture content (% w.b.): 95.6

Parameter		*DPSD*	*CD*	*OSD*
Quantity loaded (full load) (kg)		40	3	6
Loading density (kg/m^2)		4.25	3.3	3.06
Collector area (m^2)		10	0.9	ND
Collector tilt (°)		0	0	0
Solar aperture (m^2)		10	0.9	1.96
Tray surface area (m^2)		9.4	0.9	1.96
Airflow rate (m^3/h)		555.28	61.21	ND
Drying time including nights (h), up to desired m.c. (% w.b.)		33 (16.6)	33 (23.5)	33 (55.2)
Overall drying efficiency (%)		23.11	15.83	9.73
First day drying efficiency (%)		28.99	19.99	17.64
Heat collection efficiency (%)		56.36	40.98	ND
Pick-up efficiency, up to 10 % (w.b.) m.c. (%)		61.16	40.71	ND
Average temperature of exit air (°C)	day 1	54.00 ±9.8	46.27 ±5.9	36.39 ±2.4
	day 2	54.21 ±8.0	49.55 ±7.4	36.02 ±1.6
Average relative humidity of exit air (%)	day 1	24.80 ±13.6	43.37 ±13.7	47.72 ±8.3
	day 2	22.30 ±8.2	28.02 ±10.8	48.03 ±4.4
Maximum drying temp. at no-load (°C)		70.50	60.10	38.80
Maximum drying temp. with load (°C)		64.30	56	38.80
Duration of drying air temp. 10°C above ambient temp. (h)		25	18	0

m.c. – moisture content; ND – not determined

20.45 % higher pick-up efficiency comparing to typical cabinet drier. Changes of moisture content with drying time for a typical experimental run for DPSD, CD and OSD for bamboo shoots drying are shown in Fig. 4. The moisture content of fresh bamboo shoots was almost similar during all drying tests whereas the initial values were 18.67 ±1.2 $kg\,kg^{-1}$ (db), 20.31 ±1.3 $kg\,kg^{-1}$ (db) and 18.85 ±0.9 $kg\,kg^{-1}$ (db) for DPSD, CD and OSD, respectively. From the drying curves in Fig. 3 is evident, that the fastest drying process was occurred in DPSD where the falling-rate period was achieved after 7 hours corresponding to moisture content 0.69 ±0.1 $kg\,kg^{-1}$ (db), followed by CD where the falling-rate period was achieved after 8 hours with 0.73 ±0.1 $kg\,kg^{-1}$ (db) and OSD where it took 16 hours with respective moisture content equal to 1.23 ±0.1 $kg\,kg^{-1}$ (db).

These results correspond to the fact that DPSD use forced convection ensuring higher air-flow rate which results in higher water removal from the dried bamboo shoots.

Drying rate versus moisture content during DPSD drying, CD drying and OSD are presented in Figs. 5, 6 and 7, respectively. All figures show higher drying rate at the initial stages of drying which corresponds to higher initial moisture content of the product. The drying rates decreased as moisture content reduced during drying process. No constant rate period has been observed during bamboo shoots drying while drying took place only in the falling rate period.

The following drying rate curve polynomial equations were created for bamboo shoots drying by different drying method.

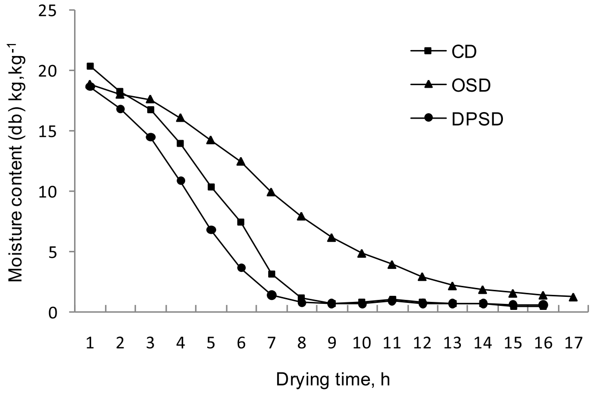

Fig. 4: *Variation of moisture content of bamboo shoots in DPSD, CD and OSD.*

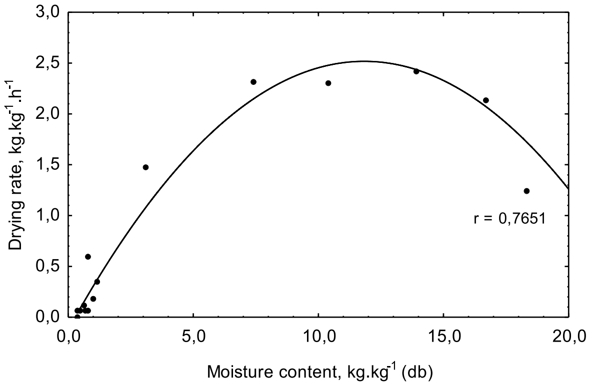

Fig. 6: *Drying rates of bamboo shoots as a function of moisture content during drying in CD.*

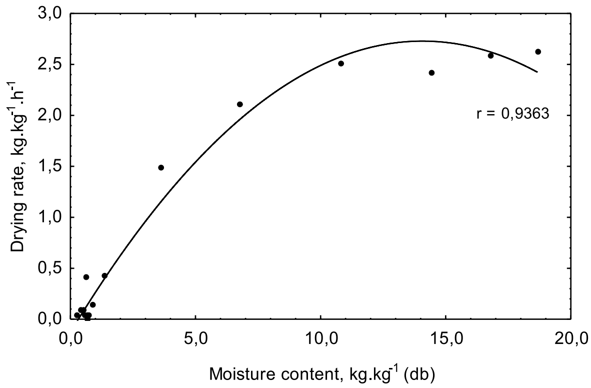

Fig. 5: *Drying rates of bamboo shoots as a function of moisture content during drying in DPSD.*

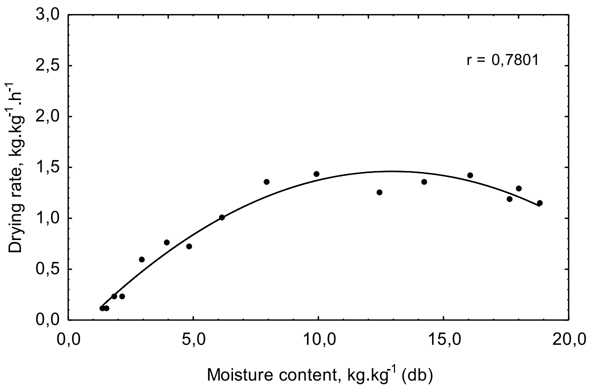

Fig. 7: *Drying rates of bamboo shoots as a function of moisture content during traditional OSD.*

For drying in DPSD:

$$DR = -0.1285 + 0.4462 * M - 0.0144 * M^2 \quad (r = 0.94) \quad (13)$$

For drying in CD:

$$DR = -0.1227 + 0.3462 * M - 0.0189 * M^2 \quad (r = 0.76) \quad (14)$$

For open-air sun drying:

$$DR = -0.1891 + 0.2548 * M - 0.0098 * M^2 \quad (r = 0.78) \quad (15)$$

According to the polynomial equations, it is obvious that highest drying rate was observed during drying in DPSD followed by drying in cabinet drier (CD) and open-air sun drying (OSD). Highest drying rate in case of DPSD correspond to highest efficiencies observed at the same drier. Similar observations were reported by Hossain & Bala (2007) during their study focused on red chilli drying where they found highest drying rate in case of forced convection solar tunnel drier which was compared to natural convection and traditional open sun drying.

3.2 Economic evaluation

Economic evaluation of both DPSD and CD solar driers is summarized in Table 2. The results show that annual costs of DPSD are significantly higher than those of CD. Higher annual costs of DPSD are the result of higher construction costs presented as total drier cost in Table 2.

Table 2: *Economic evaluation of bamboo shoots drying in DPSD and its comparison to typical CD.*

Parameter	*DPSD*	*CD*
Total drier cost (U.S. $)	2700	160
Annual cost (U.S. $)	295.43	33.92
Drying cost (U.S. $/kg)	0.28	0.49
Dried bamboo shoots per annum (kg)	1 055	69
Payback period (years)	1.6	1.7

The disproportion of total drier cost between DPSD and CD is caused by different capacities of both tested driers and by the fact that the DPSD was constructed in Czech Republic using more expensive construction materials and labor costs. It is important to note that significant reduction of total drier cost could be achieved by using local construction materials and labor force. Nevertheless the drying costs per kilogram of bamboo shoots are almost one time higher in case of CD as compared to DPSD. This is due to higher efficiency and throughput of DPSD than CD. During annual saving calculation was estimated that the farmers can sell the product on local market for the price around 2 USD/kg of dried bamboo shoots. This price was mentioned by local farmers as most typical. Based on this market price the payback period was found to be 1.6 and 1.7 years for DPSD and CD, respectively. Mainly in case of DPSD the payback period is considerably shorter as compared to the life of the drier which is 10 and 5 years for DPSD and CD, respectively.

4 Conclusion

The performances of a forced convection DPSD have been compared with those of a typical CD and a traditional open air sun drying for drying of bamboo shoots. The DPSD resulted in the lowest moisture content 16.6 % (w.b.) of bamboo shoots during 33 hours of drying including nights, which corresponds to the highest drying rate comparing to other methods. The DPSD shows higher performance as well in all measured efficiencies, of which the overall drying efficiency was about 7.3 % and 13.4 % higher in case of DPSD as compared to CD and traditional OSD, respectively. Although the construction cost of DPSD was significantly higher than in CD, the drying costs per one kilogram of bamboo shoots were by 42.8 % lower in case of DPSD as compared to CD. The payback period was more or less similar in both driers, however taking in to the consideration the life of both driers the payback period of DPSD is preferable. Hence, Double-pass solar drier was found to be technically and economically suitable for drying of bamboo shoots under the specific conditions in central Vietnam.

Acknowledgement
This research was financially supported by the Ministry of Agriculture of the Czech Republic (Project No.MZe/B/8).

References

Banout, J., Ehl, P., Havlik, J., Lojka, B., Polesny, Z. & Verner, V. (2011). Design and performance evaluation of a Double-pass solar drier for drying of red chilli (Capsicum annum L.). *Solar Energy*, 85, 506–515.

Ekechukwu, O. V. & Norton, B. (1999). Review of solar-energy drying systems II: an overview of solar drying technology. *Energy Conversion & Management*, 40, 615–655.

Ferreira, A. G., Maia, C. B., Cortez, M. F. B. & Valle, R. M. (2008). Technical feasibility assessment of a solar chimney for food drying. *Solar Energy*, 82, 198–205.

Forson, F. K., Nazha, M. A. A. & Rajakaruna, H. (2007). Modelling and experimental studies on a mixed-mode natural convection solar crop-dryer. *Solar Energy*, 81, 346–357.

Hachemi, A. (1997). Thermal heat performance enhancement by interaction between the radiation and convection in solar air heaters. *Renewable Energy*, 12, 419–433.

Hossain, M. A. & Bala, B. K. (2007). Drying of hot chilli using solar tunnel drier. *Solar Energy*, 81, 85–92.

Imre, L. (2007). Solar Drying. In A. S. Mujumdar (Ed.), *Handbook of Industrial Drying, Third Edition* chapter 13. (pp. 307–361). CRC Press, Taylor & Francis Group, Florida.

Jain, D. & Tiwari, G. N. (2004). Effect of greenhouse on crop drying under natural and forced convection I: Evaluation of convective mass transfer coefficient. *Energy Conversion & Management*, 45, 765–783.

Janjai, S., Lamlert, N., Intawee, P., Mahayothee, B., Bala, B. K., Nagle, M. & Müller, J. (2009). Experimental and simulated performance of a PV-ventilated solar greenhouse dryer for drying of peeled longan and banana. *Solar Energy*, 83, 1550–1565.

Karathanos, V. T. & Belessiotis, V. G. (1997). Sun and artificial air drying kinetics of some agricultural products. *Journal of Food Engineering*, 31, 35–46.

Koyuncu, T. (2006). Performance of various design of solar air heaters for crop drying applications. *Renewable Energy*, 31, 1073–1088.

Leon, M. A., Kumar, S. & Bhattacharya, S. C. (2002). A comprehensive procedure for performance evaluation of solar food driers. *Renewable and Sustainable Energy Reviews*, 6 (4), 367–393. doi:10.1016/S1364-0321(02)00005-9.

Murthy, M. V. R. (2009). A review of new technologies, models and experimental investigations of solar driers. *Renewable and Sustainable Energy Reviews*, 13 (4), 835–844.

Purohit, P., Kumar, A. & Kandpal, T. C. (2006). Solar drying vs. open sun drying: A framework for financial evaluation. *Solar Energy*, 80, 1568–1579.

Satya, S., Bal, L. M., Singhal, P. & Naik, S. N. (2010). Bamboo shoot processing: food quality and safety aspect (a review). *Trends in Food Science & Technology*, 21 (4), 181–189. doi:10.1016/j.tifs.2009.11.002.

Sharma, A., Chen, C. R. & Vu Lan, N. (2009). Solar-energy drying systems: A review. *Renewable and Sustainable Energy Reviews*, 13 (6-7), 1185–1210. doi:10.1016/j.rser.2008.08.015.

Sharma, V. K. (1995). Experimental investigation of different solar driers suitable for fruits and vegetable drying. *Renewable Energy*, 6, 413–424.

Simate, I. N. (2003). Optimization of mixed-mode and indirect-mode natural convection solar driers. *Renewable Energy*, 28, 435–453.

Singh, P. P., Singh, S. & Dhaliwal, S. S. (2006). Multi-shelf domestic solar drier. *Energy Conversion & Management*, 47, 1799–1815.

Walde, S. G., Velu, V., Jyothirmayi, T. & Math, R. G. (2006). Effects of pretreatments and drying methods on dehydration of mushroom. *Journal of Food Engineering*, 74, 108–115.

Xu, Y., Zhang, M., Tu, D., Sun, J., Zhou, L. & Mujumdar, A. S. (2005). A two-stage convective air and vacuum freeze-drying technique for bamboo shoots. *International Journal of Food Science and Technology*, 40, 589–595.