An experimental study for drying Pisum sativum on an electric dryer and a heat pump dryer

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Abstract. A study of drying parameters on the drying process of Pisum Sativum bean was carried out. The effects of drying temperature of moisture air from 40°C to 80°C on the drying time and on the drying kinetics were demonstrated not only on conventional electric dryers but also on heat pump dryers. Besides, checking the steady operation of the heat pump dryer was also considered. The results show that, when temperature rises, the shorter time and the faster removal of moisture content can be obtained for both dryer systems. Drying in an electric heater at 80°C took only 1 hour 45 minutes, but the broken skin of pea seeds happened. The comparison of heat pump dryer and electric dryer was presented with the shorter drying time on heat pump than electric dryer as a result of removing water vapor from moisture air at the evaporator of heat pump, it led to the reduction of specific humidity of air entering the drying chamber. And the last impressive result which can be seen is that the drying rate of a heat pump is higher than an electric dryer at the same drying temperatures beside the energy consumption of electric dryer is 2.76 times as much as that of heat pump dryer.

1 Introduction

The scientific name of Pea seeds is Pisum sativum with very rich nutrient contents around 25% protein and also rich of vitamins A, B and D. It is hard to store safety for long time due to the germination of seed with very high moisture content on the fresh seeds, with experimental test to store the fresh sativum seed for this research, just only 4 days after harvest in the environment while 5 days stored in refrigerator, the pea seeds would be germinated. So, drying is the best method to preserve products.

Many Drying technologies have been investigated and developed from the past to now, which were suitable for every product such as hot air dryer, heat pump dryer, freeze dryer, vacuum dryer. The influence of drying parameters on the drying process is one of the most important and interesting topics [1-5]. With the Pisum sativum, the research considered

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about the drying kinetics and colour of dried product had been done by Kayisoglu [1], the group of Siddique et al [2] was approached by the influence of drying time and temperature on the moisture percentage and quality of seeds. Also, some other group researchers keep working in this method for some other products such as pepper and so on. The effect of drying temperature on the quality of red bell pepper has been done by Vega-Galves et al [4], and studies about the drying characteristics and quality of difference maturity stages of pepper products were presented by Getahun et al [5].

Some researchers determined that at low temperature, the quality of dried products would be improved so they presented the new technology as a promised and new generations for drying technique, heat pump. Liu et al [6] presented the design and thermal analysis for heat pump dryer which is suitable for food products while Strommen et al [7] introduced the new drying method at low dryer temperature and they stated that drying at low temperature on heat pumps is the new generations to get the dried product with very high quality.

The purpose of this paper is to investigate the drying behaviour of thin layer drying of pea seeds, especially the drying curve and drying rate curve. Besides, the comparison of the efficiency of the drying process between an electric dryer and a heat pump dryer is considered, and the analysis of the comparison of water removal and energy performances of conventional dryer (electric dryer) and heat pump dryer is presented.

2 Methodology

2.1 Sample preparation

The Pea seeds (*Pisum sativum*) (Fig. 1) used for this test are a special product planted in Dalat City, Lamdong Province, the central highland in the middle of Vietnam. After harvesting, they are separated from the seed-pod by hand and stored in a refrigerator at 5°C until applied in experiments.

Fig. 1. Pea seeds (*Pisum sativum*).

Fig. 2. Sample analysis dryer - MX-50 WinCT – Moisture.

The initial moisture content of pea seeds is analysed by repeated drying of the samples in sample analysis dryer AND MX-50 with 0.1% accuracy as in Fig. 2. After 7 times repeated with around 5 grams of random samples, the initial moisture content of pea seeds is found to be W_o = (54.12 ± 0.95) %. The dried moisture content of pea seeds material is W_e = 14 %.

2.2 Experimental apparatus

The two dryer machines that have been used in this study are electric dryer and heat pump dryer. The electric dryer (Fig.3) was purchased with a power of 2 kW, volume 108 litters and dimensions 560x480x400 mm. The control temperature of the machine can remain the temperature in the drying chamber with the accuracy is ± 0.5°C. The Heat pump dryer is designed, and manufactured by our research group with 0.746 kW power of compressor, R407a refrigerant, 3 kW evaporator, 3.746 kW of condenser as shown in Fig. 4.

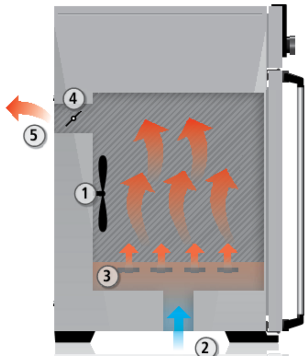

Fig. 3. Electric dryer.

1-fan, 2-inlet air, 3- electric heater, 4-damper, 5-outlet air

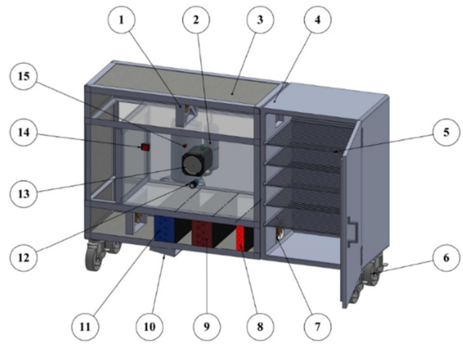

Fig. 4. Heat pump dryers.

1- exhaust air fan, 2-compressor, 3- drying trolley, 4-drying chamber, 5-drying tray, 6-wheels, 7- entrance air fan, 8-electric heater, 9-condenser, 10- drain water, 11-evaporator, 12-control temperature, 13-timer, 14- switch on/off-, 15-lamp alert.

Humid ambient air flows through the evaporator (10) to reduce the temperature and due to the lower dew point temperature, condensed water would be removed so as to influence the specific humidity of air. After that, the air stream keeps moving to the condenser (9), the temperature of air increases to the drying temperature, if the heat released from the condenser is not enough to raise the air temperature, a sub-electric heater is used. The air at drying temperature with lower specific humidity flows to the drying chamber (4) and takes moisture from the drying material as a drying process and absorbs moisture from the material for drying.

Instruments: the instruments used to measure the experimental parameters during the test are presented in Table 1 with their accuracy.

Table 1. The list of instruments.

Measure	**Instrument**	**Accuracy**
Air velocity	Testo 425	± 0.3 m/s
Temperature	Datalogger TC type K	± 0.1°C
Humidity of air (dry-wet bulk temperatures)	PH721	± 3%
Mass of material	Weight	± 10gam
Moisture of material	AND MX-50	± 0.1%

Experimental test: The test focuses on the kinetic drying due to the effect of temperature and the efficiency of a heat pump dryer compared to an electric dryer. Then the working range of experiment is shown in table 2 below:

Table 2. Experimental working conditions.

Velocity	2m/s
Temperature	40, 45, 50, 55, 60, 70, 80°C
Type of dryers	electric dryer, heat pump dryer

2.3 Moisture content and drying rate of Pea seeds

In order to determine data reduction, experiment parameters of pea seeds were used in each experiment as below:

M_o = 2 kg: mass of fresh product;
W_o = 54.12%: initial moisture content of fresh product;
W_e = 14%: moisture content of dried product;

Data reduction:

$$Water = M_o - M_e \tag{1}$$

$$Water = M_o.\frac{W_o - W_e}{100 - W_e} \tag{2}$$

$$W_e = W_o - Water.\frac{100 - W_o}{M_e} \tag{3}$$

W_t: Moisture content of product at a drying time t

$$W_t = W_o - Water.\frac{100 - W_o}{M_t} \tag{4}$$

Drying rate (DR) of pea seeds was determined:

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta t} \tag{5}$$

Where: Mt: mass of product after drying period time t;
Δt: time interval;
DR: drying rate.

3 Result and discussion

3.1 Drying pea seeds on electric dryer

Experimental tests have been done on electric dryers with a vary of temperature from 40°C to 80°C with the fresh pea seeds from 54.12% initial moisture content to 14%. The Data results show in Fig. 5, at drying temperature of 40°C a very long period of time was spent to dry pea seeds product, while at 80°C a very short time was used. More detail, it took 6 hours to dry pea seeds at 40°C, at 55°C it did take 3.5 hours and at 80°C it took only 1 hour and 45 minutes. But one important thing to get from data results is that the phenomenon of breaking the skin seed cover around the seed happened at a drying temperature of 80°C. It could be explained that due to the fast removal of moisture from the surface of seed in the short period of time, the skin layer is dried so fast.

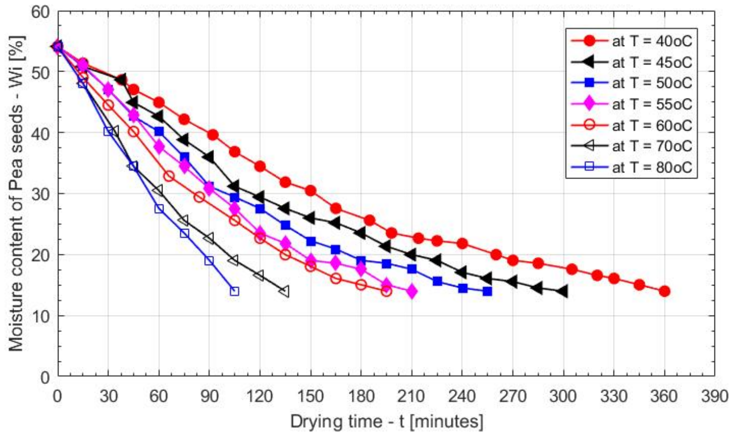

Fig. 5. Drying curves of Pea seeds on an electric dryer.

3.2 Drying pea seeds on heat pump dryer

The experiments have been performed at three different temperatures as follows: 45°C, 50°C and 55°C. As could be seen in Fig. 6, the reducing of moisture content during drying time follow by difference temperature. At the end of the series of 55°C temperature, the time is 2h45min and the product is dried to 14% moisture content, but at that time if drying temperature is 45°C the moisture content will remain 20% and needs one more hour to get the dried product. And at the last period of time at 45°C drying temperature, it can be seen that the remaining moisture in the seed is very hard to remove, that is why the reduction of the moisture content from 20% to 14% at 45°C takes one more hour and around 30 minutes at 50°C.

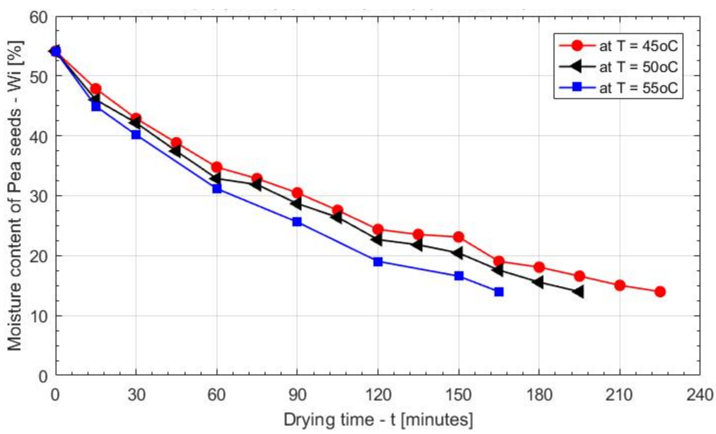

Fig. 6. Drying curves of Pea seeds on Heat pump dryer.

3.3 Comparison of the processes of drying pea seeds by electric dryer and heat pump dryer

3.3.1 Comparison of drying curves and energy consumption

Fig. 7 represents the comparison of drying pea seeds on electric dryer and heat pump dryer at the same drying temperatures. It is clear to see that drying in a heat pump is faster than in an electric dryer at all comparing temperatures.

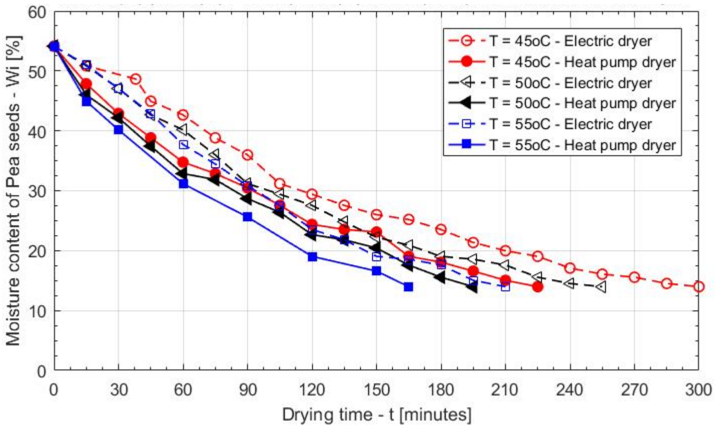

Fig. 7. Comparison of drying curves of Pea seeds on electric and Heat pump dryers.

At 50°C, drying in the electric dryer took 4 hours and 15 minutes while the heat pump took 3 hours and 15 minutes. It could be seen in Fig 8, about the steady of running heat pump system, the humid ambient air at 29.5±0.4°C, around 77% humidity flows through evaporator, moisture air moves out of evaporator at 22±0.4°C then moves to condenser to rise temperature again to 51.1±0.9°C (take as working drying temperature 50°C) before flows to drying chamber. So that the drying air flows to the drying chamber at 51.1°C, specific humidity d = 0.015 kgw/kga instead of at specific humidity d = 0.020 kgw/kga if working with an electric dryer in the same environment.

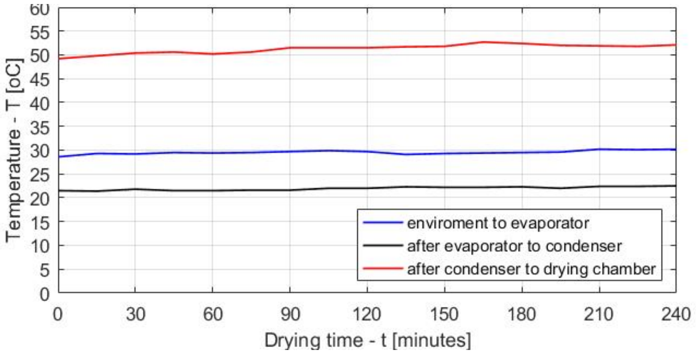

Fig. 8. The steady heat pump system.

Consider about energy consumption: The comparison of water removal and energy performances of conventional dryer (electric dryer) and heat pump dryer, a specific moisture extraction ratio (SMER) would be applied as a standard comparison to determine the performances of the electric dryer and heat pump dryer

$$SMER = \frac{Water\ removal}{electric\ consumption}. \quad (6)$$

Electric consumption of each experiment was recorded by using power instrument ATA AT-NL01, it presented total energy consumption of each experiment (kWh).

Water removal could be determined with the mass of fresh product and the mass of dry product at the end of experiment.

Table 3. The comparison of the performance of the electric dryer and heat pump dryer

Performance	Unit	Electric dryer	Heat pump dryer
Heating capacity	kW	2	3.746
Cooling capacity	kW	-	3
Shaft work	kW	-	0.746
COP	-	-	4.02
Mass of fresh product	kg	2	2
Drying temperature	^{o}C	50	50
Water removal	kgw	0.933	0.933
Working time	hours	4.25	3.5
Electric consumption	kWh	7.86	2.84
SMER	Kgw/kWh	0.12	0.33

The comparison of the performance in table 3 present at the same drying temperature at 50^{o}C, for an input of 1kWh, the electric dryer removes 0.12 kg water, while the heat pump dryer removes 0.33 kg water. In addition, the amount of energy consumption of a heat pump is only 2.84 kWh, whereas the electric dryer uses 7.86 kWh.

3.3.2 Comparison of drying rate curves:

About the drying rate, the comparison between drying in an electric dryer and heat pump at 45°C and 50°C could be observed in Fig. 9 and Fig. 10. It could take the drying at 45°C as an example, at the first drying time, when the moisture content of pea seeds is still high (at 54%) the drying rate of heat pump is greater than 0.4 and decreases gradually, while with electric dryer it is only about 0.2 to 0.3 at the same moisture content. It could be observed that during the drying process, the drying rate on the heat pump is always larger than on an electric heater.

In Fig. 11, the dried products from the experiments were collected with very good results and will be stored in the environment and in a refrigerator for a long time to check the stored time of products.

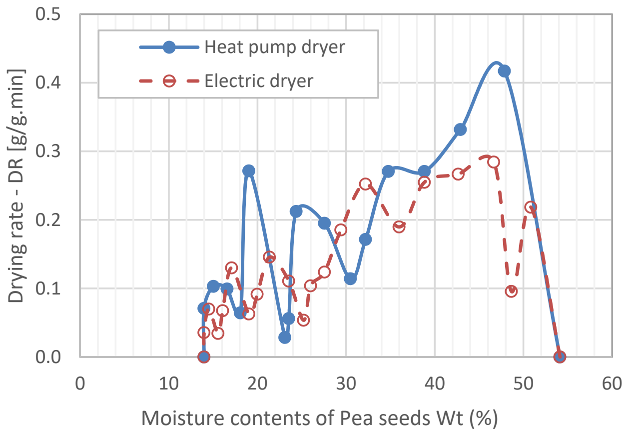

Fig. 9. Drying rate curves at 45°C.

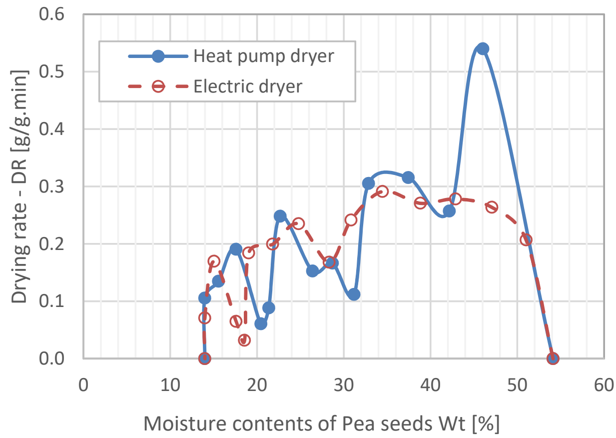

Fig. 10. Drying rate curves at 50°C.

Fig. 11. Dried Pea seeds products.

4 Conclusion

Experimental research for drying of pea seeds has been done with the consideration of drying temperature affected on the drying time and quality of products for both systems: electric dryer and heat pump dryer. The steady working operation of the heat pump also checked during the drying process and confirmed that the system works well. The comparisons between electric dryer and heat pump dryer were considered under the drying curve and drying rate of the drying process of pea seeds at the same temperature conditions. The result shows that the efficiency of the heat pump is better than the electric dryer.

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Nomenclature

M_o [kg]: mass of fresh product;
M_e [kg]: mass of dry product;
M_t [kg]: mass of product after drying period time t;
Δt [s]: time interval;
W_o [%]: initial moisture content of fresh product;
W_t [%]: moisture content of product at the drying time t;
W_e [%]: moisture content of dried product;
DR: drying rate;
SMER: specific moisture extraction ratio

References

1. S. Kayisoglu, Lat. Am. Appl. Res., **50**(3), pp. 235-240, (2020).
2. A. B. Siddique, D. Wright, Asian J. Plant Sci., **2**(13), pp. 978-982, (2003).
3. R. F. Mechlouch, B. Mahdhaoui, W. Elfalleh, A. Mahjoubi, A. B. Brahim, Int. J. Energy Eng., **4**(2A), pp. 25-32, (2014).
4. A. Vega-Galvez, R. Lemus-Mondaca, C. Bilbao-Sainz, P. Fito, A. Andres, J. Food Eng., **85**, pp. 42-50, (2008).
5. E. Getahun, M. A. Delele, N. Gabbiye, S.W. Fanta, M. Vanierschot, Case Stud. Therm. Eng., **26**, 1001052, (2021).
6. H. Liu, K, Yousaf, K. Chen, R. Fan, J. Liu, S. A. Soomro, Sustainability, **10**(9), 3216, (2018).
7. I. Strommen, T. M. Eikevik, O. Alves-Filho, K. Syverud, O. Jonassen, *The 2nd Nordic Drying Conference*, Copenhagen Denmark, June 25th -27th 2003, ISBN 82-594-2550-5 (2003).