Research Article

Iman Golpour, Mohammad Kaveh, Reza Amiri Chayjan, Raquel P. F. Guiné*

Energetic and exergetic analysis of a convective drier: A case study of potato drying process

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Abstract: This research work focused on the evaluation of energy and exergy in the convective drying of potato slices. Experiments were conducted at four air temperatures (40, 50, 60 and 70°C) and three air velocities (0.5, 1.0 and 1.5 m/s) in a convective dryer, with circulating heated air. Freshly harvested potatoes with initial moisture content (MC) of 79.9% wet basis were used in this research. The influence of temperature and air velocity was investigated in terms of energy and exergy (energy utilization [EU], energy utilization ratio [EUR], exergy losses and exergy efficiency). The calculations for energy and exergy were based on the first and second laws of thermodynamics. Results indicated that EU, EUR and exergy losses decreased along drying time, while exergy efficiency increased. The specific energy consumption (SEC) varied from 1.94×10^5 to 3.14×10^5 kJ/kg. The exergy loss varied in the range of 0.006 to 0.036 kJ/s and the maximum exergy efficiency obtained was 85.85% at 70°C and 0.5 m/s, while minimum exergy efficiency was 57.07% at 40°C and 1.5 m/s. Moreover, the values of exergetic improvement potential (IP) rate changed between 0.0016 and 0.0046 kJ/s and the highest value occurred for drying at 70°C and 1.5 m/s, whereas the lowest value was for 70°C and 0.5 m/s. As a result, this knowledge will allow the optimization of convective dryers, when operating for the drying of this food product or others, as well as choosing the most appropriate operating conditions that cause the reduction of energy consumption, irreversibilities and losses in the industrial convective drying processes.

Keywords: potato samples, convective drying, energy and exergy analyses, energy utilization, energy utilization ratio

Nomenclature

A_{dc}	area of drying chamber [m2]
C_{pda}	specific heat of the air [J/kg K] or [J/kg °C]
E_{in}	inlet energy [kJ/s]
E_{out}	outlet energy [kJ/s]
EU	energy utilization [kJ/s]
EUR	energy utilization ratio
$\dot{E}x$	exergy [kJ/s]
$\dot{E}x_{in}$	exergy inlet [kJ/s]
$\dot{E}x_{loss}$	exergy loss [kJ/s]
$\dot{E}x_{out}$	exergy outlet [kJ/s]
h_{dai}	enthalpy of inlet air [kJ/kg]
h_{dao}	enthalpy of outlet air [kJ/kg]
h_{fg}	latent heat of vaporization of water [kJ/kg]
IP	improvement potential [kJ/s]
$\dot{m}_{da}$	air mass flow rate [kg/s]
$\dot{m}_{in}$	inlet mass flow [kg]
$\dot{m}_{out}$	outlet mass flow [kg]
$\dot{m}_{v}$	mass transfer rate [kg/s]
MC	moisture content [%]
p	significance level
SEC	specific energy consumption [kJ/kg]
T	temperature [°C] or [K]
V_a	velocity of the air [m/s]
w	weight of product [kg]
w_{dao}	humidity of the air [kg/kg]

Greek symbols

ρ_a	specific mass of the air [kg/m3]
η_{ex}	exergy efficiency
φ	environment air relative humidity [%]

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* **Corresponding author: Raquel P. F. Guiné,** CERNAS-IPV Research Centre, Polytechnic Institute of Viseu, Campus Politécnico, Viseu, Portugal, e-mail: raquelguine@esav.ipv.pt, tel: +351-232-226641, fax: +351-232-426536

Iman Golpour: Grupo de Investigaciones Termoenergéticas (GIT), Universidad Politecnica de Madrid, Madrid, Spain; Department of Mechanical Engineering of Biosystems, Urmia University, Urmia, Iran

Mohammad Kaveh: Department of Biosystems Engineering, College of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran

Reza Amiri Chayjan: Department of Biosystems Engineering, Faculty of Agriculture, Bu-Ali Sina University, Hamedan, Iran

1 Introduction

Until now, food drying constitutes an operation very much in use in the food industry either as a final or as an intermediate operation for the preservation of foods (Nazghelichi et al. 2010). Fresh fruits and vegetables are extremely perishable because of their high moisture content (MC). Drying is most commonly used in a diversity of thermal energy applications as one of the most convenient methods that minimize product loss while at the same time turning the packing, handling and transporting operations easier and cheaper, due to the lower weight and volume of the dried products (Stanisławski 2005; Golpour et al. 2017). One of the crucial problems when analysing drying operations is to seek the reduction in the costs associated with energy sources, in order to increment efficiency in drying facilities while also leading to dried products of high quality (Doymaz 2012; Darvishi et al. 2014). Convective drying done with the circulation of heated air remains as the most widespread method employed to reduce the moisture in fruits and vegetables with a high ratio of heat and mass transfer (Kaleta et al. 2013; Kaveh et al. 2018).

Thermodynamic analysis plays a pivotal role when analysing the efficiency of energy utilization (EU) in industrial processes. Furthermore, exergy analysis, in particular, has proven as an essential instrument to design, analyse and optimize thermal systems. This aims at evaluating the energy available at different points of the system and offers useful information that allows choosing appropriate operating conditions and parameters to design engineering systems (Aghbashlo et al. 2008). Exergy is defined as the maximum work produced in a system to take it to an equilibrium state with the environment, taken as reference (Castro et al. 2018). In thermodynamics, the exergy efficiency offers a real measure of the performance of drying operations.

Some studies have been done to analyse exergy in drying operations. By analysing the energy and exergy in a system for drying of chilli pepper pieces, Akpinar (2004) found that the range of exergy for drying was from 67.28% to 97.92%. Additionally, it was also observed that the energy consumption ratio diminished with increasing temperature of the drying air, leading to an increase in the exergy efficiency (Akpinar 2004). When performing energy and exergy analyses for a solar drying process applied to pistachios, it was observed that the highest efficiency of exergy usage was achieved when exergy losses were minimal (Midilli and Kucuk 2003). Azadbakht et al. (2017) evaluated the energy and exergy loss for the drying of eggplant performed in a fluidized bed dryer. They studied the effects of independent variables such as temperature, flow rate of the drying air and sample size on the dependent variable energy consumption and exergy loss. Yu et al. (2020) studied energy and exergy efficiency for the convective drying of carrot cubes and concluded that the energy loss due to outlet air and also the irreversibility loss of thermodynamic process diminished both when the relative humidity of the drying air augmented. Yogendrasasidhar and Pydi Setty (2018) evaluated the exergy and energy analyses of Kodo millet and Fenugreek seeds dried in a fluidized-bed drier and found that the energy utilization ratio (EUR) increased with increasing temperature and air velocity and the exergy loss increased with increasing temperature but decreased with air velocity. Şevik et al. (2019) analysed the performance of two solar-based dryers for drying of mint leaves and apple slices based on the energy and exergy. They found that the energy efficiency was lower for the solar drier as compared with the solar drier assisted by an infrared lamp. Bühler et al. (2018) evaluated the energy and exergy performance of a milk processing industry and reported that their results could potentially be extended for the optimisation of other dairy industrial plants.

Potatoes are a very high-demand product in the consumer market all over the world and are widely available everywhere. Because drying is a way of conservation that eliminates many storage problems for potatoes, some studies have devoted to the drying of potatoes, using different methodologies and different approaches. Regarding the drying of potatoes, specifically, the work done by Djebli et al. (2020) presented the mathematical modelling of the drying process, but for the solar drying, i.e., using the Sun as an energy source. The work done by Qiu et al. (2019) focused on the drying of potato slices by different methods, but evaluated the product characteristics and functional properties. Also, the work done by Onu et al. (2020) focused on the drying of potatoes, but the aim was to optimize MC reduction.

The literature review showed that, although there is considerable information available for energy and exergy analyses in drying processes, there is a lack of knowledge about the effect of drying condition on energy and exergy for the convective drying of potatoes. Therefore, the objective of this study was to present energy and exergy analyses of potato in convective drying at different conditions of air temperature and air velocity and also to find the most suitable conditions to minimize EU and exergy losses during the drying of potatoes.

2 Material and methods

2.1 Sample preparation

Freshly harvested potatoes were purchased from a local market and maintained in double layers of polyethylene bags in a refrigerator at temperature 3 ± 1°C before the essays. The initial MC of fresh potato was determined by weight loss until constant weight using an oven dryer (70 ± 1°C for 24 h), and it was found to be 3.99 ± 0.30 (kg water/kg dry solids).

The potato slices were squared with 4 cm by 4 cm and the thickness was 4 mm.

2.2 Experimental equipment and procedure

The essays for the drying of potato samples were performed in a convection hot-air dryer developed in the Department of Biosystems Engineering, Bu-Ali Sina University, Iran (Figure 1). The dryer is a centrifugal fan comprising a single-phase electrical motor (0.375 kW), plus the air heating unit, which is located behind the fan, and has six heating parts (electrical with 2 kW). The drying chamber is cylindrical in shape, with 150 mm in diameter and 320 mm height. A digital thermostat (Model of Atbin mega, Iran) is used to control the entering air temperature, and an inverter (Model of Vincker VSD2, Taiwan) allows controlling the air velocity. Additionally, the properties of the air were also monitored, temperature and relative humidity, respectively, by a thermometer (Model of Lutron TM-903, Taiwan) and a hygrometer (Model of Lutron TM-903, Taiwan). The potato slices with 40 g were displayed on a single layer over the tray, which was then placed inside the chamber. The drying experiments were conducted at different drying air temperatures (40, 50, 60 and 70°C) and air velocities (0.5, 1.0 and 1.5 m/s). The temperature and relative humidity inside the drying chamber were recorded and also the inlet and outlet temperatures of drying air were registered for all essays.

2.3 Theoretical principle

2.3.1 Energy analysis

The generic equation for mass conservation of the drying air can be expressed as follows (Darvishi et al. 2014):

$$\sum \dot{m}_{\mathrm{in}} = \sum \dot{m}_{\mathrm{out}} \tag{1}$$

The general equation of energy conservation has the form given as follows:

$$\sum E_{\mathrm{in}} = \sum E_{\mathrm{out}} \tag{2}$$

The EU calculated by applying the first law of thermodynamics (the principle of energy conversation) can be expressed as follows (Corzo et al. 2008):

$$\mathrm{EU} = \dot{m}_{\mathrm{da}} \left(h_{\mathrm{dai}} - h_{\mathrm{dao}}\right) \tag{3}$$

The air mass flow rate $\dot{m}_{\mathrm{da}}$ was obtained using the following equation (Aghbashlo et al. 2008):

$$\dot{m}_{\mathrm{da}} = \rho_{\mathrm{a}} V_{\mathrm{a}} A_{\mathrm{dc}} \tag{4}$$

The enthalpy of drying air can be determined as follows (Nazghelichi et al. 2010):

$$h_{\mathrm{da}} = C_{\mathrm{pda}}(T - T_{\infty}) + h_{\mathrm{fg}} w \tag{5}$$

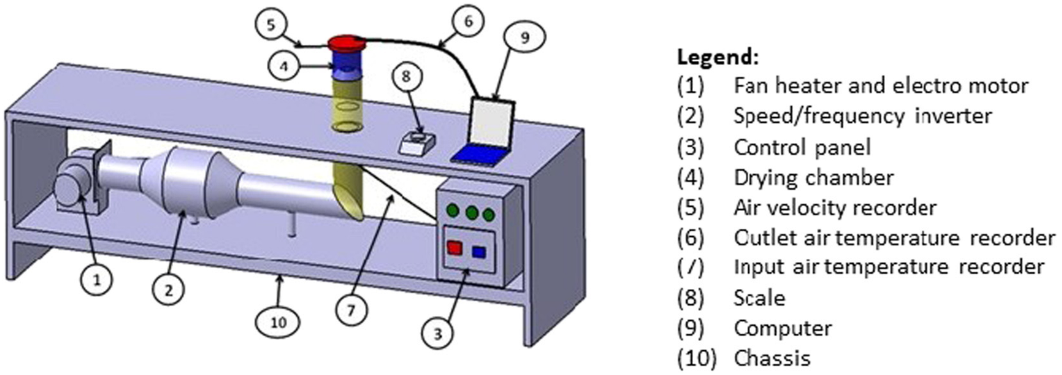

Figure 1: Schematic representation of the laboratory-scale fluid-bed dryer.

The specific heat capacities (C_{pda}) of drying air inlet and outlet were obtained by (Nazghelichi et al. 2010) the following formula:

$$C_{\mathrm{pda}} = 1.004 + 1.88\,w \tag{6}$$

Also, the following equation was generally used to calculate the humidity ratio of the air (kg water/kg dry air) (Akpinar 2004; Corzo et al. 2008):

$$w = 0.622\frac{\varphi P_{\mathrm{vs}}}{P - P_{\mathrm{vs}}} \tag{7}$$

Humidity ratio of inlet and outlet air was calculated by the following (Akpinar 2004):

$$w_{\mathrm{dao}} = w_{\mathrm{dai}} + \frac{\dot{m}_{\mathrm{v}}}{\dot{m}_{\mathrm{da}}} \tag{8}$$

Moreover, the mass transfer rate $\dot{m}_{\mathrm{v}}$ is obtained by the given formula:

$$\dot{m}_{\mathrm{v}} = \frac{W_t - W_{t+\Delta t}}{\Delta t} \tag{9}$$

The EUR of the drying chamber was calculated using the following equation (Midilli and Kucuk 2003):

$$\mathrm{EUR} = \frac{\dot{m}_{\mathrm{da}}\,(h_{\mathrm{dai}} - h_{\mathrm{dao}})}{\dot{m}_{\mathrm{da}}\,(h_{\mathrm{dai}} - h_{\mathrm{dae}})} \tag{10}$$

One other relevant aspect to consider when finding the suitable conditions for drying processes is the amount of SEC. The energy necessary to dry 1 kg of fresh potato was calculated according to the following equation (Kaveh et al. 2018):

$$\mathrm{SEC} = \left(\frac{C_{\mathrm{pa}} + C_{\mathrm{pv}}}{V_{\mathrm{h}}}\right)(T_{\mathrm{in}} - T_{\infty})\left(\frac{Q_t}{m_{\mathrm{v}}}\right) \tag{11}$$

2.3.2 Exergy analysis

The inlet, outlet and losses of global exergy were calculated based on the second law of thermodynamics. The values of the exergy flow at steady-state points and also the ratio of exergy variation for the process to perform the exergy analysis to the drying chamber were determined (Midilli and Kucuk 2003).

Accordingly, the general form of the applicable exergy equation was employed for steady-flow systems (Castro et al. 2018).

$$\dot{\mathrm{Ex}} = \dot{m}_{\mathrm{da}}\,C_{\mathrm{pda}}\left[(T - T_{\infty}) - T_{\infty}\ln\left(\frac{T}{T_{\infty}}\right)\right] \tag{12}$$

In this study, the exergy loss is the rate of exergy of evaporation for drying the products and the exergy input is the rate of exergy of the drying air entering the dryer column (Syahrul et al. 2002).

The exergy loss in the drying chamber can be determined as follows (Aghbashlo et al. 2008):

$$\sum \mathrm{Ex}_{\mathrm{loss}} = \sum \mathrm{Ex}_{\mathrm{in}} - \sum \mathrm{Ex}_{\mathrm{out}} \tag{13}$$

The exergy efficiency can be defined as the ratio of exergy use (investment) in the drying of the product to exergy of the drying air supplied to the system (Aghbashlo et al. 2008):

$$\eta_{\mathrm{ex}} = \frac{\mathrm{Ex}_{\mathrm{in}} - \mathrm{Ex}_{\mathrm{loss}}}{\mathrm{Ex}_{\mathrm{in}}} = \frac{\mathrm{Ex}_{\mathrm{out}}}{\mathrm{Ex}_{\mathrm{in}}} \tag{14}$$

In addition, the exergetic IP rate of the convective dryer was determined using the following equation (Khanali et al. 2013):

$$\dot{\mathrm{IP}} = (1\text{–}\mathrm{Ex})\,[\mathrm{Ex}_{\mathrm{in}} - \mathrm{Ex}_{\mathrm{out}}] \tag{15}$$

In this study, the ambient temperature and environment air relative humidity were taken as $T_{\infty} = 293$ K and $\varphi = 20\%$, respectively.

2.4 Statistical analysis

A statistical treatment was applied to the results, by means of analysis of variance (ANOVA) aiming at identifying differences between the average values for some properties in between different groups (three or more groups). This was complemented with Tukey's *post hoc* test to identify where the differences occurred. For all statistical treatments, SPSS software version 26 was used (SPSS Inc.) and a level of significance of 5% was considered when conducting the analyses.

3 Result and discussion

3.1 Energy analysis

The energy analysis of convective drying of potato slices was performed based on the data obtained from the experimental essays. Figure 2 presents the experimental curves for EU and EUR, obtained for the convective drying of potato samples at four levels of air temperature

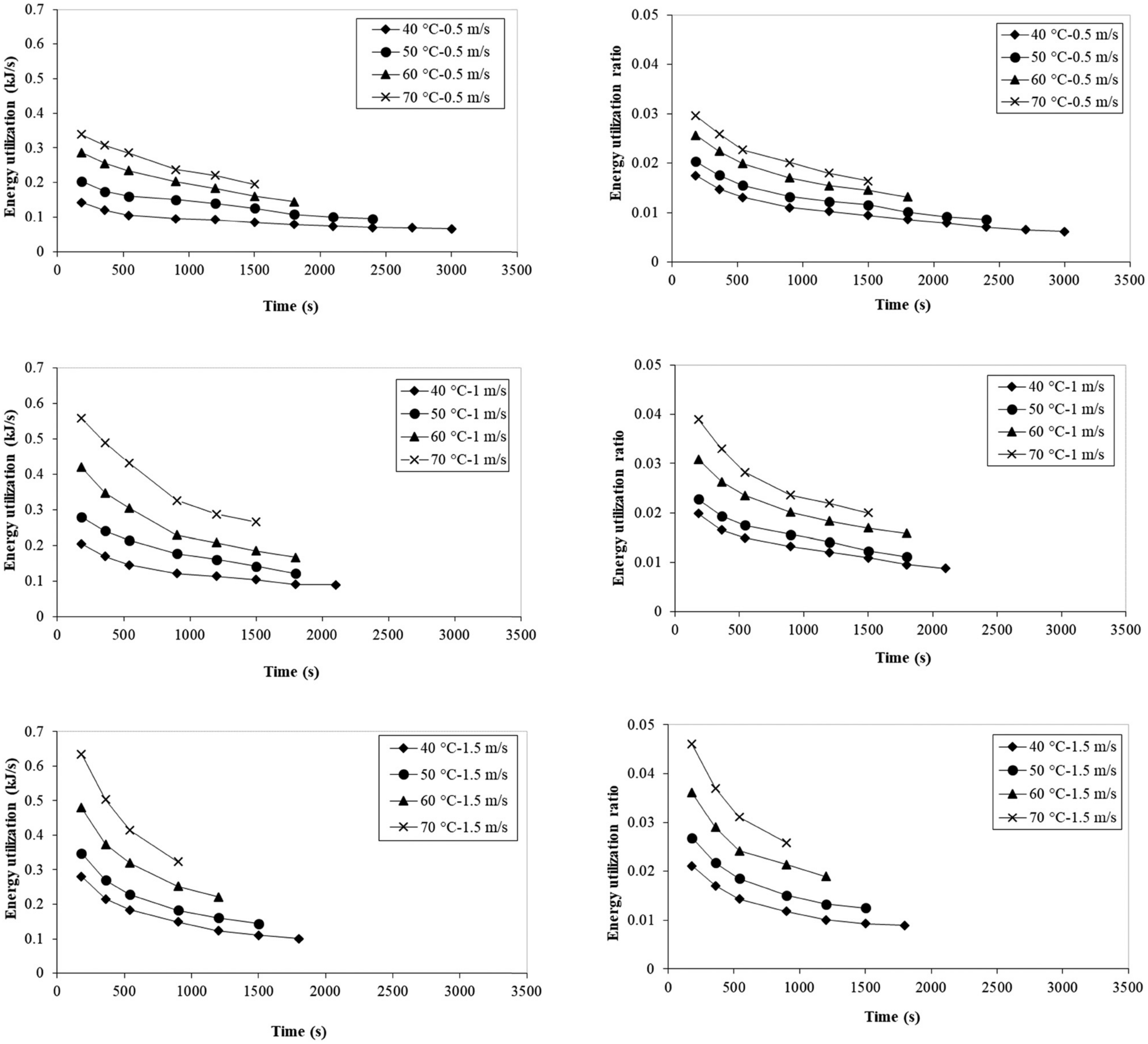

Figure 2: Influence of drying air temperature and flow rate on EU and EUR during drying of potatoes in convective dryer.

(40, 50, 60 and 70°C) and three levels of air velocity (0.5, 1.0 and 1.5 m/s). The curves showed that the maximum values of EU and EUR were 0.634 kJ/s and 0.046, respectively, corresponding to the air temperature of 70°C and the air velocity of 1.5 m/s. Moreover, the minimum values of EU and EUR were 6.56×10^{-2} kJ/s and 0.006, respectively, for the inlet air temperature of 40°C and the flow rate of 0.5 m/s. The results also showed that EU and EUR decreased persistently along the drying process. The EU and EUR were higher at the beginning of the drying process, because of the fast moisture evaporation from the potato samples, and then both decreased rapidly because the remaining moisture evaporates from the sample at a much slower rate. Consequently, the results showed that the EU and EUR increased with increasing temperature of the drying air, regardless of the airflow rate, because higher temperatures lead to a faster reduction in the MC of the product. In this way, higher temperatures promote more intense heat transfer leading to higher mass transfer in the diffusion of the water from inside the food and its evaporation at the surface. Therefore, it can be hypothesized that most of the energy supplied to the drying apparatus was utilized to promote the moisture evaporation from the potato samples, thus being eliminated at the cost of increased energy spending. Similar outcomes have been found by some authors who studied how the air temperature influenced EU and EUR for different

Table 1: Specific energy consumption for the thin-layer convective drying of potatoes

Temperature (°C)	SEC (kJ/kg)		
	0.5 m/s	1 m/s	1.5 m/s
40	1.94×10^5	2.10×10^5	2.21×10^5
50	2.22×10^5	2.41×10^5	2.65×10^5
60	2.46×10^5	2.69×10^5	2.95×10^5
70	2.60×10^5	2.85×10^5	3.14×10^5

systems (Midilli and Kucuk 2003; Akpinar 2004; Nazghelichi et al. 2010). Akpinar (2004) reported the values of EU in the range of 190 to 3,733 J/s for convective drying of red peppers in the temperature range from 55 to 70°C. Midilli and Kucuk (2003) reported the EU values between 0 and 891 J/s for the drying of pistachio. The values of EU found by Nazghelichi et al. (2010) for the drying of carrot cubes were in the range of 105 to 1,949 J/s.

Table 1 presents the values of SEC for the different experimental essays for the convective drying of potatoes, i.e., at different temperatures and flow rates. The results showed that for all drying conditions tested, SEC values increased with increasing temperature and also that increasing airflow rate caused a pronounced growth in SEC. The maximum value of SEC for potato drying was 3.14×10^5 kJ/kg and it was obtained for the drying with hot air at 70°C and 1.5 m/s, while the minimum value of SEC was 1.94×10^5 kJ/kg, for 40°C and 0.5 m/s. The high values of SEC found for high temperatures and air velocities can be explained by the additional cooling of the sample surface that happens due to these experimental conditions.

3.2 Exergy analysis

3.2.1 Exergy loss

Figure 3 shows the influence of drying air temperature and flow rate on the exergy loss for the convective drying of potato slices. The results illustrated that the exergy loss augmented with increasing air temperature and velocity. The range of values for exergy loss was 0.006–0.037 kJ/s for all air temperatures and velocities essayed, corresponding the highest value to the operating conditions of air velocity 1.5 m/s and temperature 70°C, while the lowest value was for the air temperature of 40°C and air velocity of 0.5 m/s. These results indicate that by increasing the temperature and velocity, a growth is observed in the input exergy to the drier, meaning that a larger quantity of the input exergy is underutilized, leaving the drier without being used to evaporate the moisture contained in the potato samples. Moreover, due to a decrease in the global heat transfer coefficient, the exergy loss rate diminishes at lower values of the drying air temperature and velocity (Dincer and Sahin 2004). Similar findings were reported in the works of Nazghelichi et al. (2010) and Azadbakht et al. (2017). Nazghelichi et al. (2010) reported the values of exergy loss in the range of 0.2 to 1.6 kJ/s and Azadbakht et al. (2017) in the range of 1 to 4 kJ/s. Finally, these results show that only a small part of exergy is used, so that some energy is still available when the air leaves the drying chamber.

3.2.2 Exergy efficiency

Figure 4 presents how the drying air temperature and velocity influenced the exergy efficiency for the thin-layer drying of potato slices. The results indicate that the exergy efficiency raised with increasing air temperature but diminished for increasing air velocity. Similar results were also obtained in other works (Colak and Hepbasli 2007; Khanali et al. 2013). Colak and Hepbasli (2007) found the values of exergy efficiency increasing from 69% to 92% for a temperature increase in the range of 40 to 70°C and also Khanali et al. (2013) reported the increase of exergy efficiency from 64% to 85% with increasing temperature in the range of 50 to 70°C.

The energy use was raised because of the highest quantity of energy supplied to the system, which was used for the moisture evaporation. Anyway, increasing the drying air temperature causes an increase in the exergy efficiency, being this effect due to the fact that the surface of the product is saturated with moisture, thus needing more heat to evaporate the free moisture. Nevertheless, when this moisture concentration on the surface becomes lower, moisture starts diffusing from the internal structure of the potato samples to the surface (Rabha et al. 2017). Additionally, for higher airflow rates, a decrease is observed in the output air exergy as compared to the input air exergy. In this way, the exergy efficiency is equal to 85.85%, 82.90% and 80.62% for a temperature of 70°C and air velocities equal to 0.5 m/s, 1 and 1.5 m/s, respectively. The minimum and maximum values of exergy efficiency were 57.07% and 85.85% at air temperatures of 40°C and 70°C and drying air velocities of 1.5 m/s and 0.5 m/s, respectively. Therefore, for the drying temperature of 70°C, the exergy

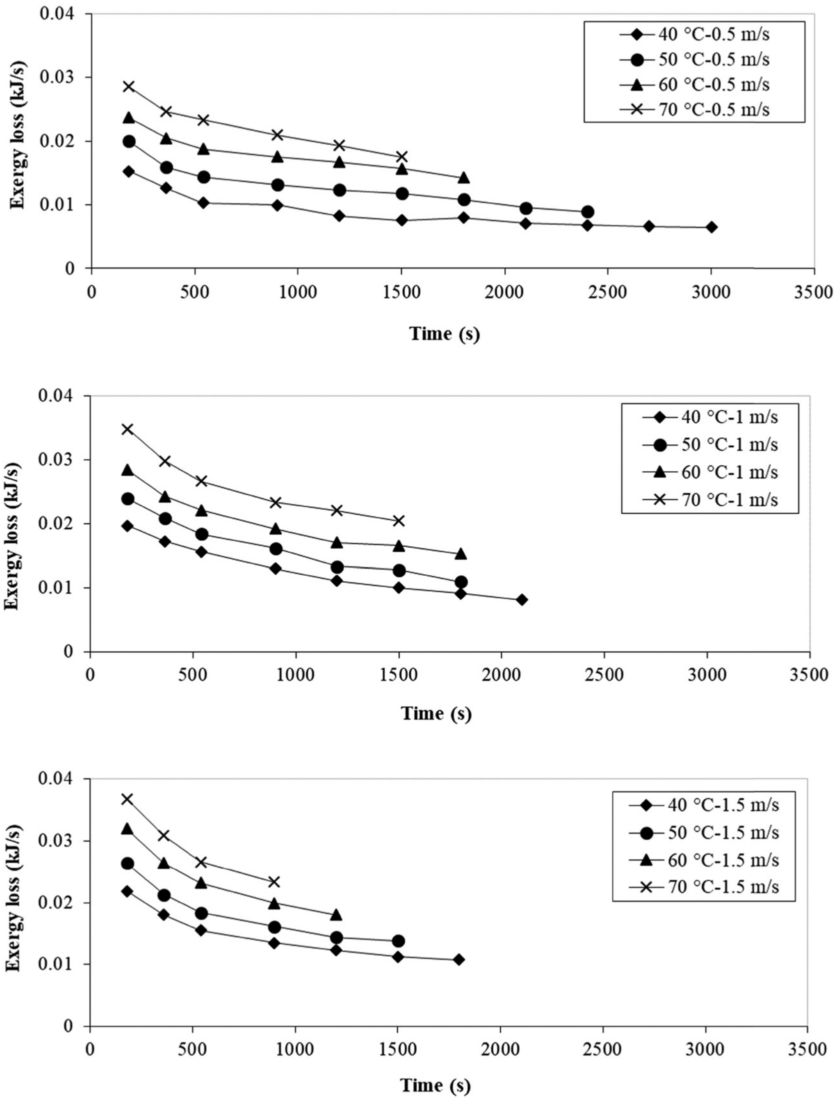

Figure 3: Influence of air temperature and velocity on the exergy losses for the drying of potato slices.

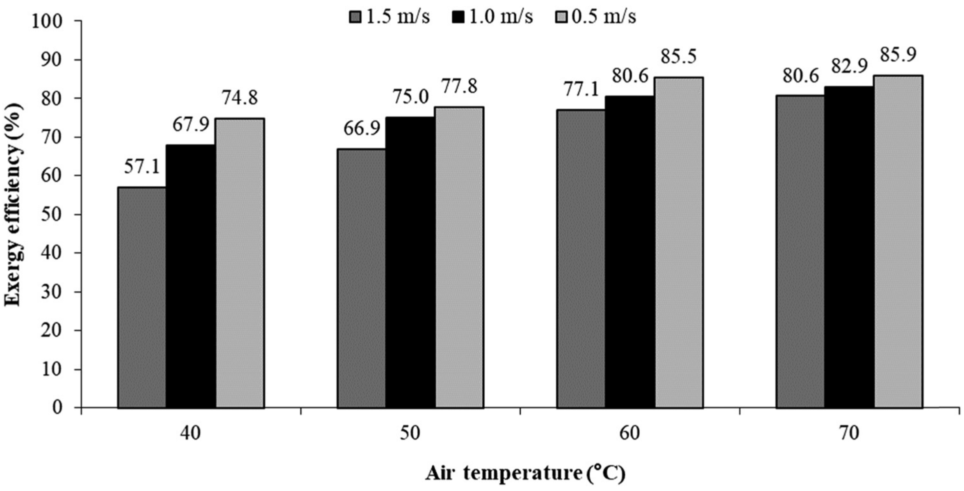

Figure 4: Influence of air temperature and velocity on the exergy efficiency for the drying of potato slices.

efficiency was above 80%, which was slightly higher when compared to the values of about 73% reported by Castro et al. (2018) for onion drying by convection dryer. This is relevant given the importance that exergy efficiency has for the industrial processes, both at the economic and energetic levels.

The results obtained noticeably indicate the outflow exergy of the drying system as being the most problematic issue in terms of thermodynamic inefficiency, revealing that a large portion of the thermal exergy provided to the system is lost through the outlet air. This is a clear problem for this kind of drying process. After this first factor, the second most significant contribution to an inefficient use of energy is consists in the exergy lost from the dryer when the temperature of the exterior boundary of the drier is higher than the ambient temperature. Consequently, minimizing the heat transfer across the boundary of the system, i.e., the drier walls, could mitigate the exergy lost. Measures such as isolating the dryer surroundings, sealing the dryer body, designing and selecting appropriate materials with heat barrier properties, as well as selecting the optimum drying conditions could all contribute to minimize the exergy lost and enhance the thermodynamic efficiency of industrial dryers.

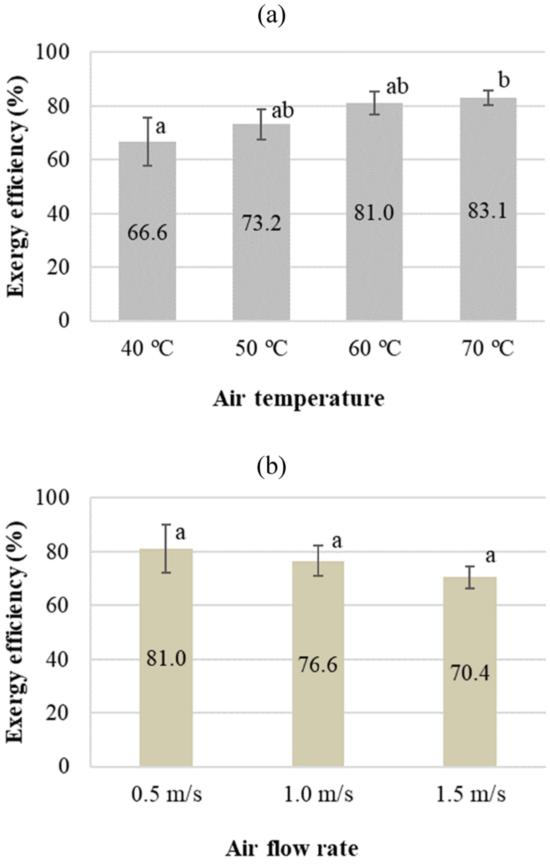

Figure 5: Mean values of exergy efficiency for the drying of potato slices for: (a) fixed temperature or (b) fixed flow rate (bars with the same letter correspond to the values not significantly different according to ANOVA and Tukey's *post hoc* test with $p < 0.005$).

Figure 5 shows the mean values of exergy efficiency considering each of the temperatures and each of the flow rates tested. The graph of Figure 5(a) is evidenced that the values obtained for each temperature (by varying the velocity) are relatively uniform, given the low values of the standard deviation. This further confirms that by increasing temperature exergy, the efficiency increases with significant differences between the values for 40 and 70°C, but not for the intermediate temperatures. Figure 5(b) also reveals that for specific air velocity, the values of exergy efficiency are also relatively similar, again with low values of standard deviation. It is also noticed that increasing the airflow rate slightly decreases the mean value of exergy efficiency, although these differences are not significant. These results allow verifying the relative influence of each of the variables over the exergy efficiency, which seems to be more influenced by temperature than air velocity in the range of experimental conditions tested.

3.2.3 Improvement potential rate

Figure 6 presents the values for the (IP) rate of the drying chamber for the drying of potatoes, for variable air temperatures and velocities. The results show that the values of the IP rate vary from 0.00164 to 0.00463 kJ/s so that the maximum IP rate obtained in the convective dryer was 0.00463 kW at the drying air temperature of 40°C and air velocity of 1.5 m/s, whereas the lowest value of the IP rate occurred at the drying air temperature of 40°C and the air velocity of 0.5 m/s. Beigi et al. (2017) reported the values between 27.3% and 59.21% for this parameter for the deep-bed drying of rough rice. Hence, the results showed that the values of the IP rate increased with raising the air velocity in the potato drying while the influence of the air velocity was not clear. Taking into account that the conservation of exergy is verified only for reversible processes, the observation of growth in exergy loss indicates a detachment from reversibility, causing IP rate to increase.

Figure 7 presents the results for exergy IP rate, for fixed temperature and fixed flow rate. The results indicate that there were no significant differences

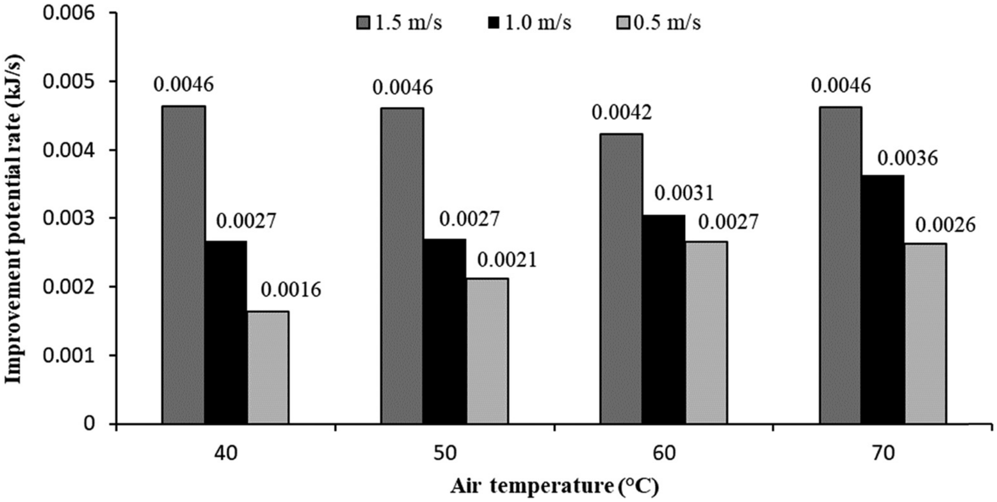

Figure 6: Influence of air temperature and velocity on the exergy IP rate for the drying of potato slices.

regarding the mean values obtained for each of the four temperatures studied, although the mean values increased very lightly with increasing temperature (Figure 7(a)). On the contrary, when the air velocity was increased, the IP rate increased, with significant differences between the mean values at 1.0 and 1.5 m/s (Figure 7(b)). These results indicate that the IP rate is more influenced by the airflow rate than by the temperature, for the conditions tested.

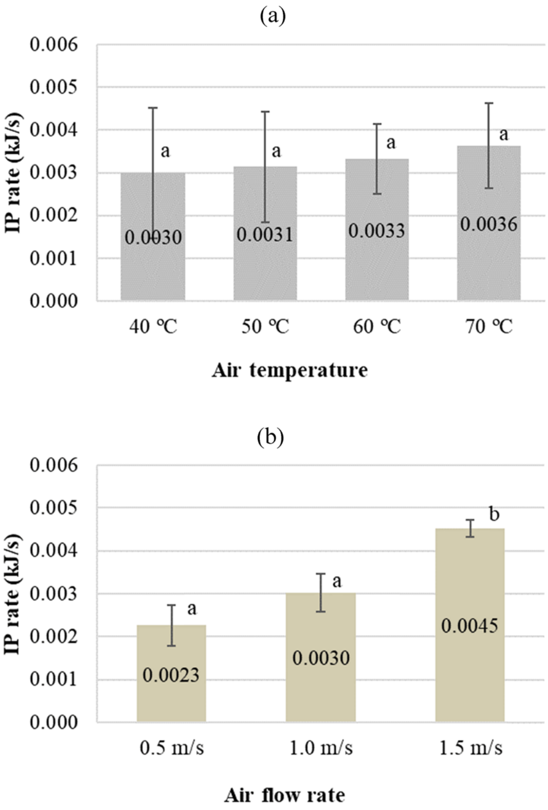

Figure 7: Mean values of exergy IP rate for the drying of potato slices for: (a) fixed temperature or (b) fixed flow rate (bars with the same letter correspond to the values not significantly different according to ANOVA and Tukey's *post hoc* test with $p < 0.005$).

4 Conclusions

The exergy performance of the convective drying of potato slices was achieved for variable drying conditions, specifically inlet drying air temperature and flow rate. The EU, EUR, exergy loss and exergy efficiency increased with increasing drying temperature. The SEC increased with increasing air temperature and air velocity. The minimum exergy losses were observed for air velocity of 0.5 m/s and air temperature of 40°C, and contrarily, the maximum exergy losses were verified for an airflow rate of 1.5 m/s and air temperature of 70°C. The range of values for the exergy efficiency of the drying chamber was from 57.07 to 85.85%. So as to promote a more efficient usage of the energy and exergy, it is suggested to reuse the energy leaving the dryer by feeding it back to the drying chamber. Nevertheless, a full optimization study should be carried out in order to find the most suitable energy and exergy for this particular process, the thin-layer convective drying of potato slices.

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