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Full Length Research Paper

Comparison of a gas fired hot-air dryer with an electrically heated hot-air dryer in terms of drying process, energy consumption and quality of dried onion slices

Hany S. EL-Mesery and Gikuru Mwithiga*

School of Engineering (Bio-resources Engineering Group), University of KwaZulu-Natal, Pietermaritzburg, South Africa.

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Onion slices were dried in either a gas-fired hot air dryer or an electrically heated hot air dryer at air temperatures of 50, 60 or 70°C, and at air flow velocities of 0.5, 1.0 or 2.0 m/s. Records of the drying rates and energy consumption were kept by using electronic weighing balances and an electric metering device. The results showed that the drying rate and final product quality in the two dryer were not significantly different at $P < 0.05$ level for the same setting of air flow and air temperature, and all dried products were of acceptable quality in terms of rehydration ratio and appearance. The specific energy consumption was found to decrease with increase in temperature but to increase with increase in air velocity in both dryers and for all conditions within the range of these experiments. The thermal efficiency of the gas dryer was between 54.87 to 69.52% while that of the electrically heated dryer was between 31.27 to 53.84%. The thermal efficiency of both dryers increased with increase in temperature and decreased with increase in air velocity. However, there was considerable difference in the energy consumption and efficiency of the two dryers, with the gas-fired dryer being more efficient at all settings.

Key words: Electrical dryer, gas-fired dryer, drying, specific energy consumption, modeling, thermal efficiency, rehydration, forced convection.

INTRODUCTION

Drying is defined as a process of moisture removal caused by simultaneous heat and mass transfer. Heat transfer from the surrounding environment evaporates the surface moisture of the drying object. The moisture inside the product can be transported to the surface of the product and then evaporated, or evaporated internally at a liquid vapors interface and then transported to the surface as vapour (Gogus, 1994). Moreover, drying is one of the oldest methods of food preservation, and it represents a very important aspect of food processing. Longer shelf-life, product diversity and substantial volume reduction are the reasons for the popularity of dried fruits and vegetables, and this could be expanded further with improvements in product quality and process applications. Such improvements could lead to an increase in the current acceptance of dehydrated foods in the market (Maskan, 2001).

Onion (*Allium cepa* L.) is considered to be one of the most important crops in all countries. It is the round edible bulb of *A. cepa*, a species of the lily family and one of the oldest cultivated vegetable crops. Red, white and gold onions represent the most common varieties of this species. Growers distinguish them also between freshly consumed onions and onions for industrial transformation on the basis of sowing time and technique, harvesting time and bulb size among other characteristics (Bonaccorsi et al., 2008). Onion is a strong-flavoured vegetable used in a wide variety of ways, and its

*Corresponding author. E-mail: gikurum@yahoo.com.

characteristic flavour (pungency) or aroma, biological compounds and medical functions are mainly due to their high organo-sulphur compounds (Corzo-Martinez et al., 2007). Fresh onions usually have an initial moisture content of about 7.3 to 5.99 g of water/g of dry matter, which is equivalent to a moisture content of 85.7 to 88.0% in wet basis (Sharma et al., 2005). Kumaret al. (2006) reported an initial moisture content of 85 to 90% (w.b.). Other researchers who have reported that onions are generally dried from an initial moisture content of about 86 to 7% (w.b) or less for efficient storage and processing are Sawhney et al. (1999) and Sarsavadia (2007).

The advantage of dehydrated foods is that low moisture content slows down or prevents the growth of microorganisms that causes spoilage reactions (Babalis and Belessiotis, 2004). The desire to optimize the dehydration processes in the agro-food industry has led to the study of technological variables involved in the process itself. For a realistic techno-economic evaluation of a dryer installation, certain performance factors such as energy efficiency, thermal efficiency, adiabatic thermal efficiency, specific heat energy consumption, specific electric energy consumption, specific volume of dryer and specific fuel consumption are often used (Arinze et al., 1996; Pakowski and Mujumdar, 1995). Modelling of the dehydration process is also very useful in the design and optimization of dryers (Brook and Bakker-Arkema, 1978; Bertin and Blazquez, 1986; Vagenas and Marinos-Kouris, 1991). However, theoretical simulations of the drying process (moisture migrations in the product being dried) require a substantial amount of computing time because of the complexity (although realistic) of the diffusion equations governing the process (Sharp, 1982).

The objective of this study was to compare the performance of a gas heated dryer to that of an electrically heated dyer. The specific objectives were to determine the (1) energy consumption and efficiency of each dryer, (2) rate of drying of onion slices in a gas heated and electric heated dryer and (3) the quality of onion slices dried under different temperature conditions in both the gas heated and electrically heated dryer with respect to rehydration and visual appearance.

MATERIALS AND METHODS

Fresh onions of Giza 6 variety were procured from a local market, packed into plastic bags, and kept refrigerated at 4°C and relative humidity of 60% (Ertekin and Gedik, 2005). The onion remained in storage for up to three weeks. Two hours before each experiment, the onions were taken out of the refrigerator and medium size bulbs (5 to 8 cm in diameter) were selected, hand peeled and cut into slices of approximately 5 ± 0.1 mm thickness using a sharp stainless steel knife. The direction of cutting was perpendicular to the vertical axis of the bulb.

Three measurements were made on each slice for its thickness using a caliper, and the average of the three readings recorded as the thickness. The onion slices were spread as a single layer onto a tray which was then inserted into the drying chamber. The initial moisture content of fresh onion was measured by drying a 20 g sample in an oven set at 105°C for 24 hours and was expressed as $g_{water}/g_{dry\ matter}$ (AOAC, 1990).

Experimental dryer

The choice of which energy to use to dry products depends on many factors including the initial moisture content, type of product and how fast one needs to dry the product before deterioration commences. Wilcke (2008) advocates the use of a combination of the common gas-fired dryers and natural air drying when dealing with corn. The drying experiments were conducted in two similar convective hot-air dryers as shown in Figure 1. Two types (electric and butane-gas) of heat energy sources were used in order to heat the drying air. The dryers consisted of three basic units; a fan that provided the desired drying air velocity, a heating unit coupled with an air temperature control system, and the drying chamber. The drying chamber was 50 cm long, 40 cm across and 40 cm high, and was made from galvanized sheet metal of 1.5 mm thickness. Air was forced through the dryer using an axial flow blower, and the velocity of air flow was controlled by an air-control-valve and measured using a vane anemometer sensor with an accuracy of ± 0.1 m/s that was placed two centimeters above the drying tray.

For the electrical dryer, the air was heated while flowing through two spiral type electrical heaters that had a heating capacity of 1.5 kW each (Figure 1a). These electrical heaters were turned off or on simultaneously through a thermostat air temperature controller that was placed over the drying tray. The controller could maintain the air temperature within ± 0.1°C of the set limit. An electric meter was used to measure the amount of energy consumed by the electric heaters during each experiment. The butane gas dryer was designed just like the electrical dryer in all aspects except for the source of heat. In this dryer, the source of heat was a gas burner placed in the plenum chamber and connected to a gas cylinder that was outside the dryer (Figure 1b). The gas burner was positioned in a way that it allowed the air passing through the chamber to be heated to the set drying air temperature. The temperature control system consisted of a precision thermostat connected to a gas solenoid valve for automatic closing and re-opening the gas flowing to the ignition nozzle. For re-ignition of the gas nozzle, a small tube branched from the main gas tube and was fixed in a position facing the gas nozzle and kept in continuous ignition throughout the drying process. A constant temperature during the experiment could be maintained with an accuracy of ± 0.1°C by the repeated on/off action of the burner.

Experimental procedure

In each dryer, the air temperature was set at 50, 60 or 70°C, while the air velocity was set at 0.5, 1.0 or 2.0 m/s. Drying runs at each experimental setting of air temperature, and air flow velocity were repeated three times, and the average values recorded. Since there were three temperature settings, three air velocity settings and two dryers, there were a total of 18 runs. Also, the dryers were run empty for about 30 min in order to establish steady state conditions before the freshly cut onion slices measuring approximately 100 g were spread on a tray in a single layer and inserted into the dryer. The mass of the drying onions was measured using a digital electronic balance every 15 min throughout the drying period. The digital top pan balance (1000 ± 0.01 g) was kept near the drying unit. Drying of onion slices was terminated when moisture content approached 7% (w.b).

Energy consumption

The energy consumed by the electrical dryer (ED) was determined

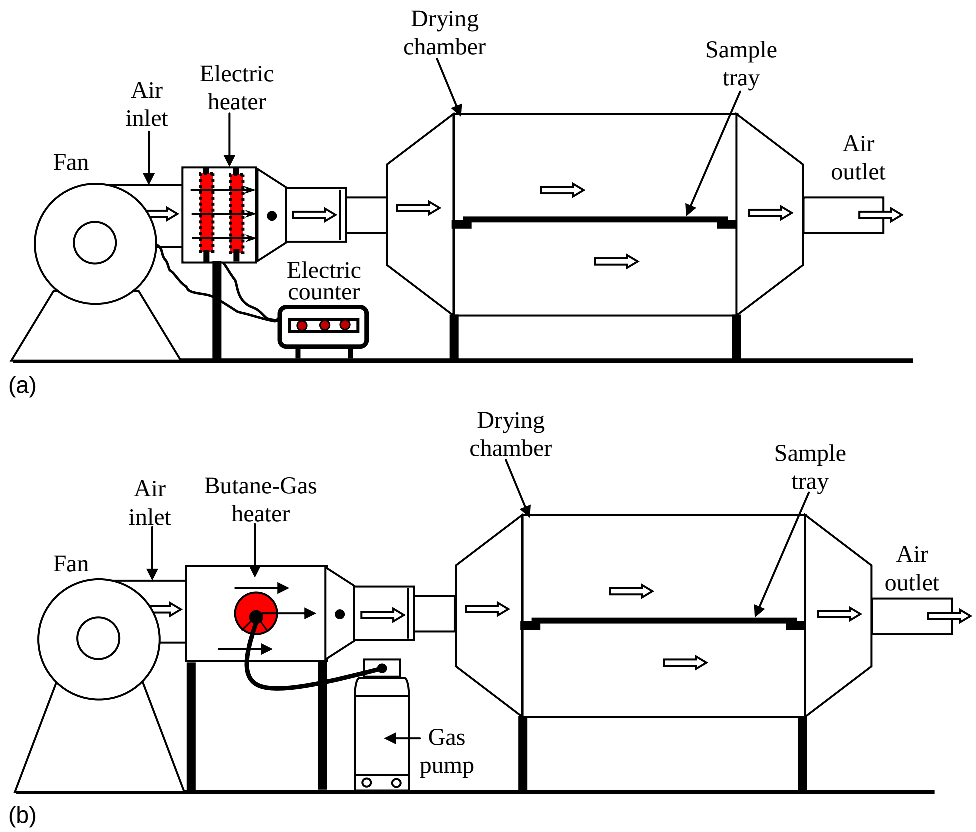

Figure 1. Schematic diagram of the experimental setup. (a) convective hot-air dryer using electric heater, (b) convective hot-air dryer using butane-gas heater.

using a digital electric counter with 0.01 kWh precision. This measuring device was connected to the system in such a way that it could measure all the energy going into the heating elements. The total energy consumed in one run was determined by taking a reading of the digital counter just before inserting the drying materials into the dryer and then taking another reading as soon as drying was terminated on reaching a moisture content of 7% (w.b.). The difference in the two readings was later converted into total energy consumed and reported in kilojoules. The energy consumption of butane gas dryer (GD) was determined by weighing the gas cylinder using a balance that had a precision of ± 0.1 g. The mass of the gas bottle was measured just before the drying product was inserted into the dryer, and again immediately after terminating the drying process. The difference in mass was then converted into consumed energy (Q_G) by the use of Equation 1.

$$Q_G = m_G H \tag{1}$$

Where m_G is the mass of consumed butane gas in kg and *H* is the lower heating value of butane gas and was assumed to be 45600 kJ/kg (Demirbas, 2006). The energy released on combustion of the gas or the energy measured electrically can be related to energy actually used to evaporate the water as presented in Equation 2 in what is commonly referred to as specific energy consumption (SEC) (Jindarat et al., 2011).

$$SEC = \frac{\text{Total electrical or gas energy}}{\text{Mass of water removed during drying}} \tag{2}$$

Thermal efficiency

The heat of vaporization of water from an open water surface at atmospheric pressure is 2500 kJ/kg of water evaporated, when the water temperature is 0°C. This value decreases rapidly as the temperature of water rises and reaches approximately 2250 kJ/kg of water at temperature of 100°C (Popiel and Wojtkowiak, 2007). When water is evaporating from a drying material, the energy required is higher than when it is evaporating from an open surface. In our case, the latent heat of water of vaporization was taken to be 2382.7, 2358.5 and 2333.8 kJ/kg at 50, 60 and 70°C in accordance with Jindal and Reyes (1987). From these values, we can now calculate the energy used to evaporate water as presented in Equation 3.

$$Q_W = mL \tag{3}$$

Where Q_w is total energy used to evaporate the water, *m* is the mass of water removed during the drying run and *L* is the appropriate latent heat of vaporization of water with respect to the temperature of drying air. The efficiency (E) of the dryer can then be computed as the ratio of energy gainfully used in evaporating the water (Q_w) to that of consumed energy (Q_G), and then expressed as a percentage in the form of Equation 4.

$$E = 100\left(\frac{Q_W}{Q_G}\right) \tag{4}$$

Table 1. Mathematical models applied to the drying curves.

No.	Model	Equation	References
1	Newton	MR = exp (-Kt)	Ayensu (1997)
2	Henderson and Pabis	MR = a.exp(-Kt)	Henderson and Pabis (1961)
3	Page	MR = exp ($-Kt^n$)	Page (1949)
4	Modified Page	MR = exp [$-(Kt)^n$]	Ozdemir and Devres (1999)

Rehydration ratio

Just as it is important to dry a product in order to enhance its storability, it is also important to rehydrate some products in readiness for their consumption. The ability of a product to rehydrate and return to the condition it was in before it was dried is a measure of how good the drying process is. Well dried products therefore have good rehydration characteristics, and the properties of their rehydrated products compare well with those of fresh products (Bobic et al., 2002). There are three simultaneous processes that occur during the rehydration process: the imbibition of water into dried material, the swelling, and the leaching of soluble contents. The rehydration ratio of dried onion slices were determined by immersing 10 g of dried sample in 50 ml of water that was at a temperature of 35°C. Samples were drained and weighted after 5 h (Kim and Toledo, 1987). The rehydration ratio was calculated as the ratio of mass of rehydrated sample to mass of dry sample using Equation 5 (Bobic et al., 2002).

$$Rehydration\ ratio = \frac{Mass\ after\ rehydration}{Mass\ before\ rehydration} \quad (5)$$

Modelling of the drying curves

Thin-layer modeling of the drying behavior is important for investigation of the drying characteristics of onion slices. For mathematical modeling, the equations in Table 1 were tested in order to select the best model for describing the drying behavior of onion slices during drying (Ayensu, 1997; Henderson and Pabis, 1961; Page, 1949; Ozdemir and Davis, 1999). The moisture ratio of onion slices during drying was calculated using the equation; MR = ($M - M_e$) / ($M_o - M_e$), where M is the moisture content of the product at any time, M_o is the initial moisture content and M_e is the equilibrium moisture content. The values of M_e are relatively small compared with M or M_o and can therefore be set to zero for air drying temperatures such as those used in this study (Akgun and Doymaz, 2005; Mitra et al., 2012; Bennamoun and Belhamri, 2003; Kiranoudis et al., 1992). Thus, the moisture ratio can be simplified to MR = M / M_o. The fitness of the tested mathematical models to the experimental data was evaluated using the coefficient of determination (R^2) and standard error (SE) as presented in Equations 6 and 7, respectively. The higher the R^2 values and the lower the SE values were, the better was the goodness of fit of the model (Ertekin and Yaldiz, 2004).

$$R^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp.i} - MR_{Pre.i}\right)^2}{\sqrt{\left[\sum_{i=1}^{N}\left(MR_{exp.i} - MR_{Pre.i}\right)^2\right] * \left[\sum_{i=1}^{N}\left(MR_{exp.i} - MR_{Pre.i}\right)^2\right]}} \quad (6)$$

$$SE = \frac{\sqrt{\sum_{i=1}^{N}\left(MR_{exp.i} - MR_{Pre.i}\right)^2}}{N-1} \quad (7)$$

Where $MR_{exp,i}$ stands for the experimental moisture ratio found in the measurements, $MR_{pre,i}$ is the predicted moisture ratio for this measurement and N is the number of observations.

RESULTS AND DISCUSSION

Drying behaviour of onion slices

The drying curve of onion slices dried in either an electric or a gas heated dryer are presented in Figures 2 and 3, respectively. Increasing the air temperature resulted in an increase in the drying rate of onion slices, and this was true both in the gas dryer and the electric dryers. When the air velocity was increased while holding the air temperature constant, it resulted in a decrease in the drying duration for both the gas and electric dryer. However, it was noticed that the automatic on/off action of the gas dryer was much more frequent when compared to that of the electrical dryer, and this was probably because the heater elements of the electrical dryer retained some thermal energy even after switching off. The durations required to reduce the moisture content to 10% in the electrical dryer when the air velocity was set at 0.5 m/s and when drying at air temperatures of 50, 60 and 70°C, were 585, 495 and 420 min, respectively. For the electrical dryer, these drying durations decreased to 510, 405 and 300 min, and to 420, 330, and 255 min, when the air velocity was increased to 1.0 and 2.0 m/s, respectively. The drying times for the gas dryer were close to those of the electrical dryer for each setting of air temperature and velocity. These drying durations are within the range of those found in previous studies (Demir et al., 2004; Kumar et al., 2006; Menges and Ertekin, 2005).

Modelling of drying curves

Statistical analysis was carried out in order to fit the drying rate data to the four models that are presented in Table 1. The results of the analysis are presented in Tables 2 and 3 for both the electric dryer and gas dryer, respectively.

As shown in the tables, all studied models gave consistently high coefficient of determination (R^2), which means that all models could describe the drying behavior of onion slices well. However, among the four models, the Page model had the highest average R^2 values and

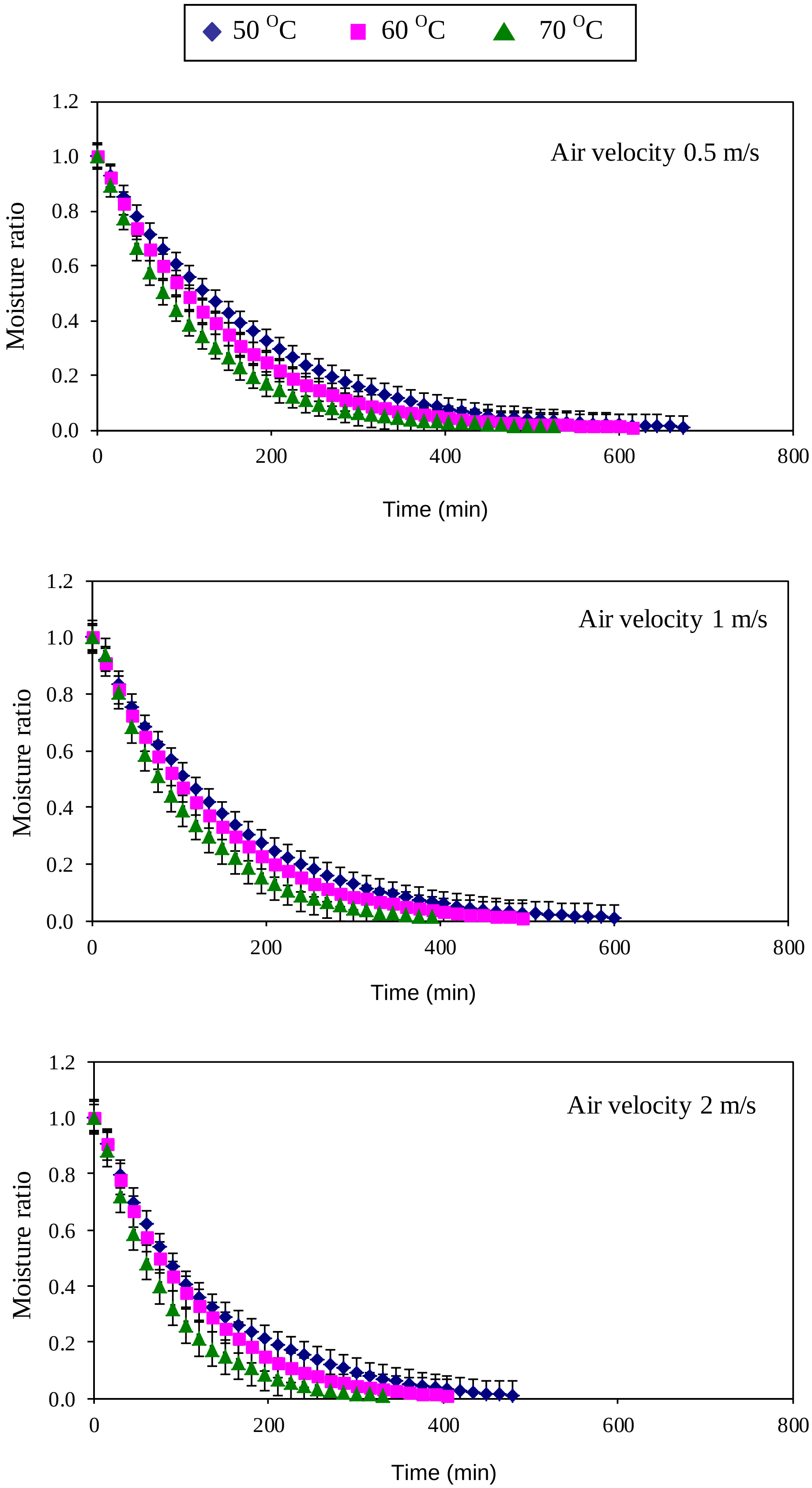

Figure 2. Moisture ratio as a function of drying for electric dryer at different air temperature and different air velocity.

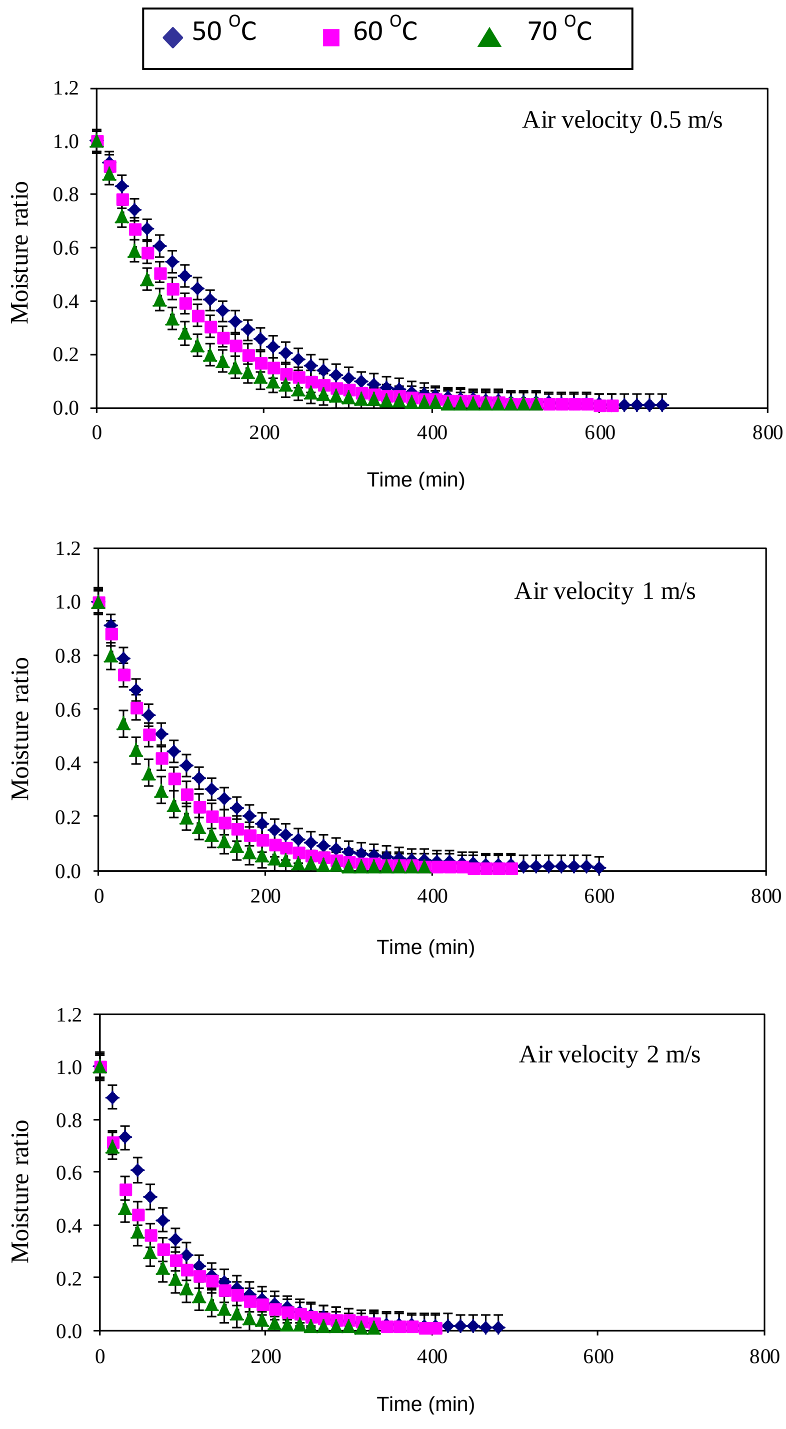

Figure 3. Moisture ratio as a function of drying for butane-gas dryer at different air temperature and different air velocity.

lowest average SE values over all temperatures and all air velocities, and this was true even when data sets from both dryers were considered. Other researchers who have found the Page model to be highly representative of drying behavior include Kumar et al. (2006) and Wang (2002).

Specific energy consumption

The specific energy consumptions (SEC) for both the electric dryer and gas dryer and for different air temperatures and air velocities are presented in Figure 4. It is evident from the diagram that SEC decreases with

Table 2. Statistical results obtained from different thin-layer models for the convective hot-air dryer using electric dryer.

No.	Air velocity (m/s)	Air temperature (°C)	Constant		R^2	SE
1	0.5	50	k=0.0073		0.997	5.41
		60	k=0.0082		0.995	9.09
		70	k=0.0099		0.991	9.18
	1	50	k=0.0083		0.997	8.63
		60	k=0.0104		0.993	8.20
		70	k=0.0133		0.984	9.97
	2	50	k=0.0094		0.993	4.98
		60	k=0.0121		0.991	6.73
		70	k=0.0161		0.992	9.31
	Average				0.993	7.94
2	0.5	50	k=0.0073	a=0.963	0.998	5.20
		60	k=0.0078	a=0.819	0.993	8.28
		70	k=0.0089	a=0.706	0.981	9.91
	1	50	k=0.0078	a=0.836	0.994	8.95
		60	k=0.0096	a=0.762	0.986	9.81
		70	k=0.0121	a=0.708	0.974	9.74
	2	50	k=0.0095	a=1.033	0.998	5.32
		60	k=0.0119	a=0.931	0.994	6.94
		70	k=0.0153	a=0.777	0.995	7.12
	Average				0.990	7.92
3	0.5	50	k=0.0053	n=1.057	0.999	3.91
		60	k=0.0083	n=1.004	0.999	5.04
		70	k=0.0136	n=0.954	0.998	7.66
	1	50	k=0.0082	n=1.007	0.999	5.09
		60	k=0.0124	n=0.978	0.998	6.45
		70	k=0.0236	n=0.903	0.998	5.02
	2	50	k=0.0063	n=1.072	0.999	4.51
		60	k=0.0094	n=1.049	0.998	5.31
		70	k=0.0157	n=1.011	0.999	6.11
	Average				0.998	5.46
4	0.5	50	k=0.0082	n=1.057	0.993	8.44
		60	k=0.0096	n=1.004	0.997	9.58
		70	k=0.0129	n=0.954	0.991	7.62
	1	50	k=0.0065	n=1.007	0.981	8.63
		60	k=0.0084	n=0.978	0.969	9.32
		70	k=0.0101	n=0.903	0.934	9.95
	2	50	k=0.0088	n=1.072	0.999	7.65
		60	k=0.0124	n=1.049	0.997	8.65
		70	k=0.0167	n=1.012	0.998	7.22
	Average				0.984	8.56

increase in air temperature but increases with increase in air velocity in both dryers. In the electrical dryer, when the temperature of drying air was increased from 50 to 70°C while holding the air velocity constant at 0.5 m/s, the specific energy consumption decreased from 65.45 to 43.34 MJ/kg of water evaporated. At the fixed air velocity of 2 m/s and for the same air temperature range of 50 to70°C, the specific energy consumption of the electrical dryer decreased from 84.64 to 70.59 MJ/kg of water evaporated. These figures imply that (within the range of

Table 3. Statistical results obtained from different thin-layer models for the convective hot-air dryer using butane-gas heater.

No.	Air velocity (m/s)	Air temperature (°C)	Constant		R^2	SE
1	0.5	50	k=0.0074		0.998	7.53
		60	k=0.0082		0.996	9.23
		70	k=0.0098		0.998	10.00
	1	50	k=0.0082		0.996	8.63
		60	k=0.0100		0.996	7.96
		70	k=0.0130		0.997	10.22
	2	50	k=0.0100		0.993	9.36
		60	k=0.0120		0.987	7.21
		70	k=0.0160		0.988	6.87
	Average				0.994	8.55
2	0.5	50	k=0.0074	a=1.018	0.998	8.63
		60	k=0.0077	a=0.814	0.998	9.11
		70	k=0.0088	a=0.699	0.997	9.91
	1	50	k=0.0077	a=0.853	0.998	8.95
		60	k=0.0098	a=0.805	0.993	9.81
		70	k=0.0120	a=0.705	0.976	9.74
	2	50	k=0.0099	a=0.832	0.995	8.84
		60	k=0.0110	a=0.758	0.989	9.36
		70	k=0.0140	a=0.700	0.977	9.55
	Average				0.991	9.32
3	0.5	50	k=0.0049	n=1.066	0.999	3.16
		60	k=0.0087	n=0.994	0.998	5.65
		70	k=0.0140	n=0.947	0.998	4.22
	1	50	k=0.0083	n=0.993	0.999	8.44
		60	k=0.0110	n=0.989	0.998	4.52
		70	k=0.0260	n=0.881	0.998	6.13
	2	50	k=0.0011	n=0.996	0.999	8.91
		60	k=0.0191	n=0.818	0.998	5.01
		70	k=0.0253	n=0.768	0.999	3.99
	Average				0.998	5.56
4	0.5	50	k=0.0068	n=1.066	0.993	9.88
		60	k=0.0085	n=0.994	0.997	9.58
		70	k=0.0110	n=0.947	0.998	9.36
	1	50	k=0.0085	n=0.993	0.981	8.63
		60	k=0.0100	n=0.989	0.969	10.63
		70	k=0.0160	n=0.881	0.987	9.95
	2	50	k=0.0100	n=0.996	0.991	7.65
		60	k=0.0160	n=0.818	0.997	10.99
		70	k=0.0210	n=0.768	0.998	7.22
	Average				0.990	9.32

this work) less energy goes to waste when the temperature is high and air velocity is low. The SEC values also compare to the value of 64 MJ/kg determined by Jindarat et al. (2011) for hot air drying at 70°C. Sharma and Prasad (2006) found values that ranged from 140 to 215 MJ/kg while drying garlic and their values showed a decreasing trend with increase in temperature within the range of 40 to 70°C (just like in this study), although the SEC values are decidedly higher. For the gas dryer, raising the drying air temperature from 50 to

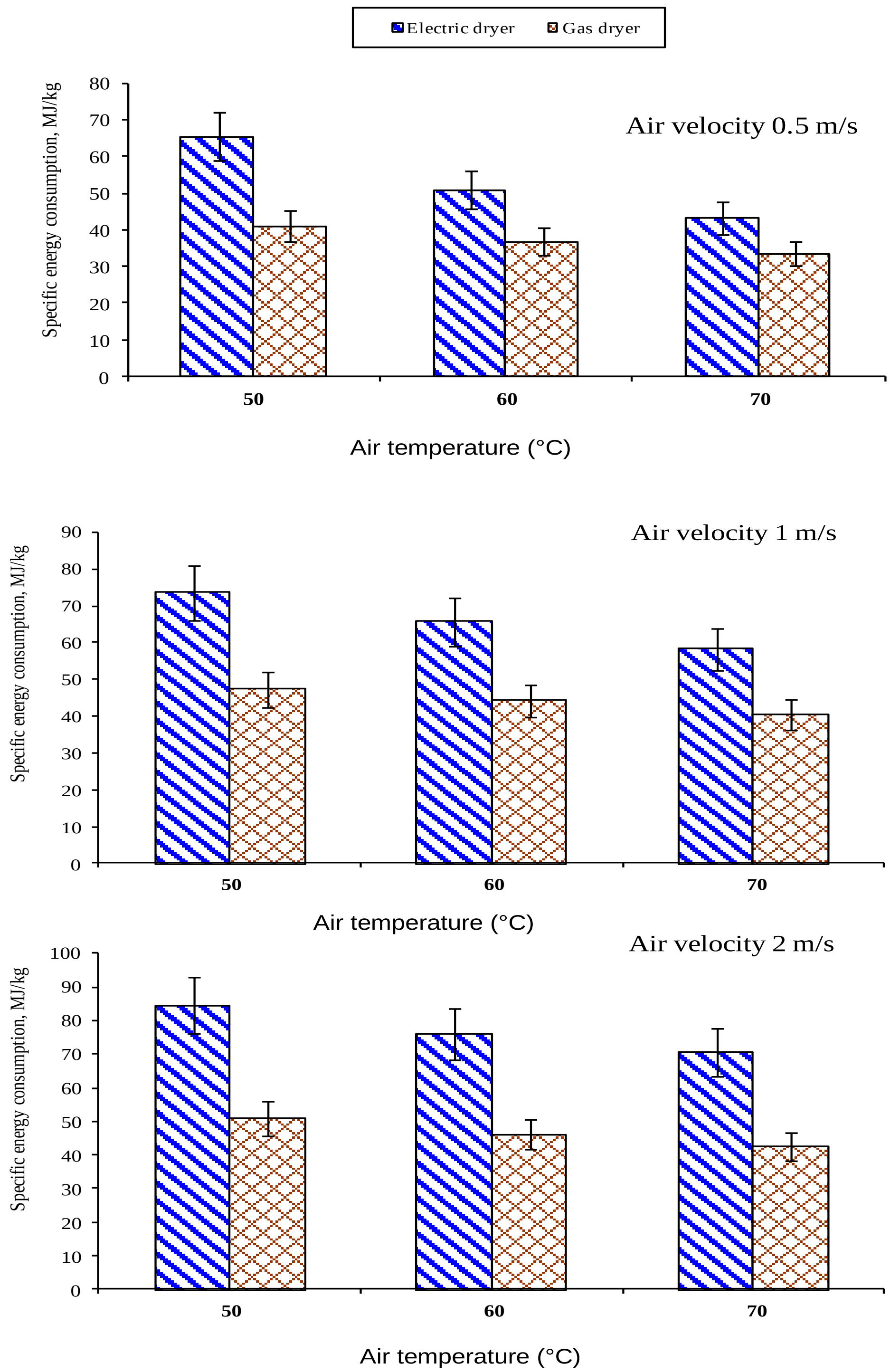

Figure 4. Specific energy consumption at different levels of drying air temperature and air velocity for both the electrical and the gas dryer.

70°C at a fixed air velocity of 0.5 m/s caused the specific energy consumption to decrease from 41.22 to 33.56 MJ/kg of evaporated water. At a fixed velocity of 2 m/s, the specific energy consumption in the gas dryer decreased from 50.89 to 42.52 MJ/kg of water evaporated, when the air temperature was increased from 50 to 70°C. Similar trends have been reported by Khoshtaghaza et al. (2007) and Aghbashlo et al. 2008. The specific energy consumption of the gas dryer was lower than that of the electric dryer at all conditions of air temperature and air flow settings. This is probably because of the longer on/off periods of the electrical

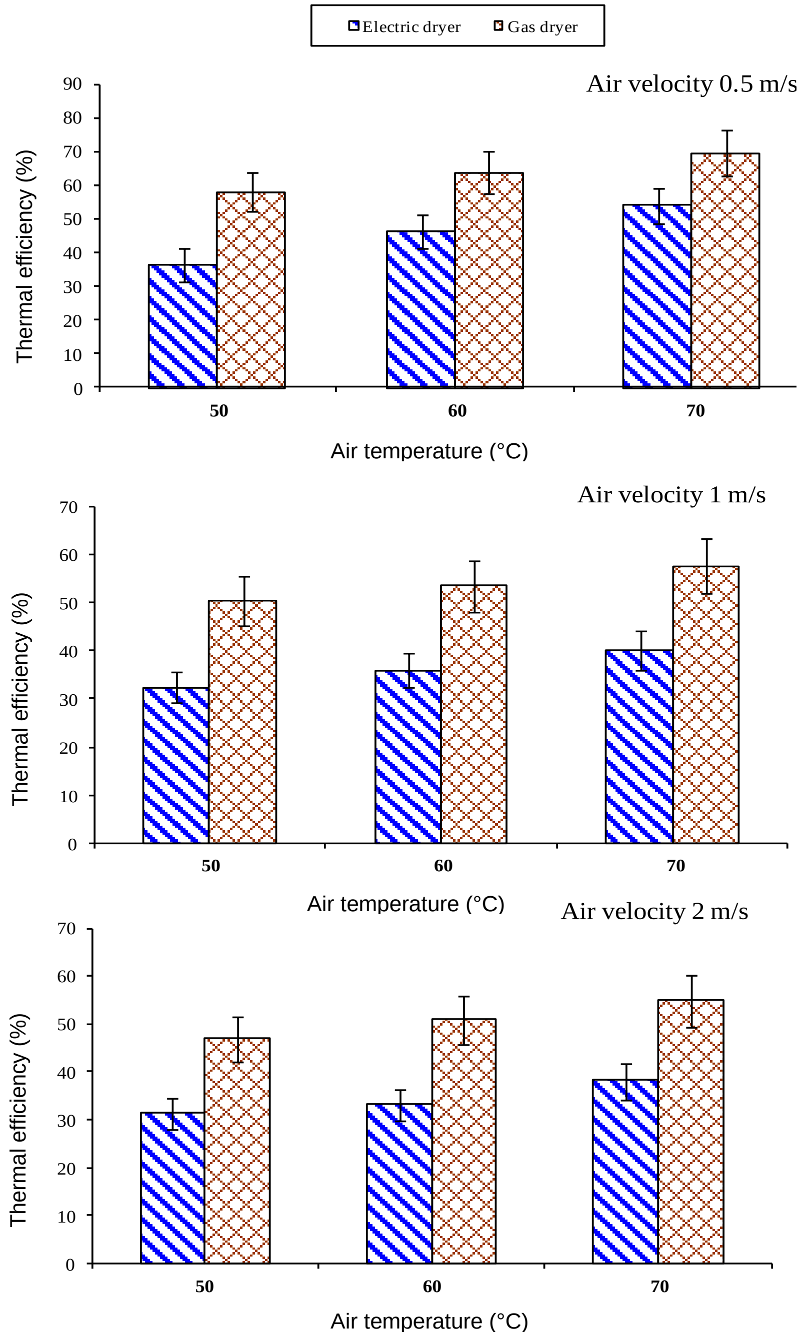

Figure 5. Thermal efficiency at different levels of drying air temperature and air velocity for both the electrical and the gas dryer.

heater elements when compared to the gas burner and the fact that the electric heaters still retained a high thermal mass even when stitched off.

Thermal efficiency

The thermal efficiencies of both the electrical dryer and the gas dryer and for different drying air temperatures and air velocities are presented in Figure 5. The thermal efficiency increased with increase in drying air temperature and decreased with increase in drying air velocity in both dryers. Similar trends have been reported by EL-Mesery (2008) and Jindal and Reyes (1987). Changing the air temperature from 50 to 70°C while holding air velocity constant at 0.5 m/s in the electrical dryer resulted in the thermal efficiency increasing from 36.38 to 53.84%, while as at a constant air velocity 2 m/s

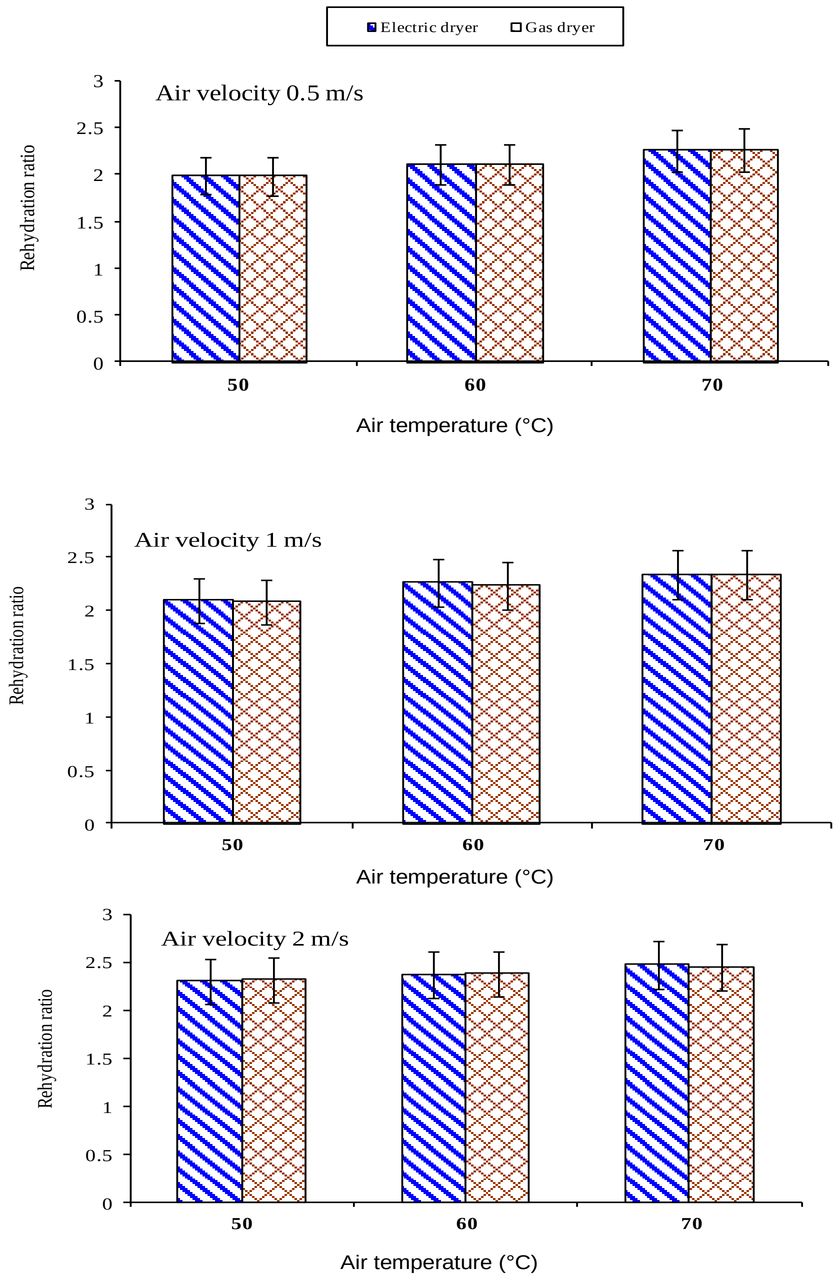

Figure 6. Rehydration ratio at different levels of drying air temperature and air velocity or both the electrical and the gas dryer.

and over the same temperature range, the thermal efficiency increased from 31.27 to 38.09%. The thermal efficiency values for the gas dryer increased from 57.8 to 69.52% when the air temperature changed from 50 to 70°C at a controlled air velocity of 0.5 m/s. When the air velocity was set at 2 m/s and the air temperature increase from 50 to 70°C, the thermal efficiency of the gas heated dryer increased from 46.81 to 54.87%. Thus, the thermal efficiency for the gas dryer was higher than that of the electric dryer at all settings of air velocity and drying air temperature.

Rehydration ratio

The rehydration ratio was considered to be one of the important quality attribute for dry onion slices in the present study. Therefore, the rehydration values of the onion slices previously dried under various drying conditions are presented in Figure 6. The rehydration ratio was found to increase with increase in drying air temperature and velocity. Changing the air temperature from 50 to 70°C while holding the air velocity constant at 0.5 m/s, in the electric dryer, caused the rehydration ratio to increase from 1.99 to 2.25. On the other hand, holding the air velocity constant at 2 m/s, and raising the air temperature over the same range (50 to 70°C) in the same dryer caused the rehydration ratio to increase from 2.30 to 2.47. The rehydration ratio of onion slices increased from 1.98 to 2.26 when the air temperature was increased from 50 to 70°C, and the air velocity remained fixed at 0.5 m/s while using the gas dryer. When the air velocity was fixed at 2 m/s while the air temperature was raised from 50 to 70°C, the rehydration ratio increased from 2.32 to 2.45. This trend was in agreement with that obtained by Sharma et al. (2005). There was no significant difference at ($P < 0.05$) between the rehydration ratios of onion slices dried under different temperature and air flow conditions in the same dryer and neither was there any significant difference between samples dried in the electrical dryer and those dried in the gas dryer. Visual inspection of the samples did not reveal any difference in appearance of dry samples previously dried in different dryers or any difference due to air temperature difference, and there were no other difference that could be attributed to the difference in terms of air velocity settings.

Conclusion

The performances of an electrically heated dryer and a butane-gas fired dryer both operating at drying air temperatures of 50, 60 or 70°C and at air velocities of 0.5, 1.0 or 2.0 m/s were investigated. The drying time decreased with increase in air temperature and air velocity in both dryers. The specific energy consumption of the gas heated dryer was lower than that of the electrically heated dryer. The thermal efficiency of the gas dryer was higher than that of the dryer that used an electrical heater. Also, the onion slices dried in both dryer, and for all drying conditions within the range of this study, and were of good quality in terms of rehydration ratio and visual appearance. Gas as a heat source appears to be better when compared to the electrical heater for this type of dryer design.

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