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# Drying of beetroots (Beta vulgaris L.) using oven dryer

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## ABSTRACT

Removal of moisture from food is popularly called drying and it is one of the most vital preservation techniques used in the food industry. In this study, the beetroots (Beta vulgaris L.) were dried in a laboratory oven dryer. The samples of fresh beetroots were dehydrated under a temperature of 50°C. The experimental study selected three different forms of the product, we choose a square form with (5 × 5 cm) and thickness e = 5 mm, a semi-circle form with thickness e = 5 mm and diameter D = 5 mm, and a triangle form with (5 × 5 × 5 cm) and thickness e = 4 mm. The main objective of the present study is to find the selection of the drying techniques essential to producing high-quality dried products in a rational time. The results give the moisture ratio of the different forms of the beetroot product as a function of time drying, while the triangle form responded to the drying process faster than the other two forms.

## KEYWORDS

Beetroots
Beta vulgaris L
Drying process
Moisture ratio
Oven dryer
Forced convection

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## 1 Introduction

Drying is the process of removing moisture from a product by evaporation up to a certain threshold value. Because the activities of the microorganisms, enzymes, or ferments in the material are suppressed by drying, the product can be stored for an extended period [1].

Foods can be dried using the sun, in an oven, in solar drying techniques, or a food dehydrator. Chabane et al., use solar drying to dry some products such as green leaves (mint) and vegetables (green pepper) [2-4]. While they use the same method that Teguia et al., use for dry fruits such as (oranges, and apricots) [2, 5].

Microwave drying is more rapid, more consistent, and more energy-efficient than hot-air convection and infrared radiation drying [6]. Furthermore, using a microwave to dry agricultural products like grains, seeds, and beans, efficiently raises their final quality [7-10], vegetables such as (potatoes, pepper, mushrooms, carrots, onions, garlic,…) [11-15], green leafy (parsley, chamomile leaves, alfa alfa, spinach,…) [16-20], fruits (apples, bananas, gripe, peach, kiwi, Pomegranate Arils,…) [20-25], nuts (walnuts, pistachios,…) [26, 27], seafood (Sardine fish) [28], medical supplies (pharmaceutical powders,…) [29], pasta [30].

Beetroot is grown in temperate regions all over the world, with the main production centers in North America, Europe, Asia, and North Africa.

The red beetroot is a traditional and widely consumed vegetable throughout the world, it has numerous applications in human nutrition. Red beets can be used as a red food colorant in a variety of forms, such as tomato paste, sauces, desserts, jams and jellies, ice cream, sweets, and cereals, as well as in dried forms such as chips, tea, powder in bakery, food supplements, and so on.

This vegetable's red pigment is known as betalain, the color and flavor of dried red beetroot are regarded as the most important quality attributes influencing the degree of consumer acceptance [31].

M. Mohammad Zadeh et al., studied how a fluidized bed dryer and a freeze dryer dried a sugar beet particle with a triangular base, they discovered that it might be preserved for a long time with no change in its sugar concentration and other qualities by removing at least 90% of the moisture content. The results of experiments in two distinct dryers revealed that while the dried material produced by the freeze dryer looks better than that produced by the fluidized bed dryer, the drying time in a fluidized bed dryer with energy carriers is significantly less than that of a freeze dryer [32].

While the goal of Amanah et al., was to test how heat and mass transport affected the drying of sliced red beetroot under the following situations: open direct sun drying (ODSD), greenhouse drying (GHD), and hybrid dryer with liquid gas (HD), in comparison to open direct sun drying.

The convective heat transfer coefficient for the hybrid dryer with the liquid gas technique was consistently higher, while for greenhouse drying was almost similar, the drying rate constant for the hybrid dryer with liquid gas is significantly higher than that for open-air direct sunlight drying, and the same for greenhouse drying [33].

Kamalakar et al., investigate how the inlet air temperature affects the way that beetroot slices dry in a microwave oven. The outcomes were compared with samples dried at the same temperatures in a tray dryer and a microwave oven, it was noted that the final moisture content of the beetroot samples obtained using the microwave oven system was lower than that of samples obtained using the tray dryer method [34].

By creating a high-quality beet powder (in terms of color and rehydration ratio) as a model system, Gokhale and Lele's research in a 10 kg/batch laboratory tray drier aimed to reduce batch time and lower power usage, the entire beet pulp was dried into a slab, and mathematical simulations of the kinetics of dehydration were conducted at various temperatures between 50 and 120°C. The temperature had an impact on the beet's ultimate color, and the lowest drying temperature resulted in the greatest color retention.

The best drying conditions necessitated a gradual temperature decrease (from 120 to 50 °C), which helped to preserve the color. By doing this, the traditional isothermal drying at 50 °C batch time of 6h was lowered to 4h [35].

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Add to that Atul Dhiman et al., discuss different heat treatment techniques and value addition for beetroot, they find that freezing effectively reduces drying time by using a spray dryer and freeze dryer to preserve the components of beetroot for use in products [36].

Navnidhi Chhikara et al., provided brief information about the compounds found in beetroot, its health benefits, and what it is useful for us to dry it to preserve its nutritional value, add its powder to many foods, and use it as a red color for products as well [37]. Bindu Bazaria and Pradyuman Kumar improved the spray drying parameters with the inlet air temperature and they found that a temperature of 160 ℃, a flow rate of 400 ml/h, and a concentration of maltodextrin of 15 % are the optimum conditions for good drying of beetroot to develop a powder production using Box-Behnken design [38]. Other researchers: Santanu Malakar et al., made a comparison between vacuum tube drying (ETSD) and a solar dryer by loading beetroot slices for drying without loading them, they obtained high results for both temperatures and low humidity without loading, and by using Weibull, Midilli, and Kucuk models to accurately describe the drying kinetics, they found that ETSD is good for drying the food commodity while retaining its quality characteristics compared to the solar dryer [39].

ATEL Yashwant Kumar et al., aimed to dry beetroot using a fluidized bed (FB) drier at various air speeds and temperatures, they found that the initial air humidity at the drying outlet increases as drying time increases but after a while, it decreases with respect to drying time increases [40].

Adam Figiel evaluated the effect of microwave power and CPD level on the kinetics of drying as well as various quality attributes of VMFD beetroot cubes, including shrinkage, texture, color, and capacity for rehydration. He concluded that early use of VMFD at high microwave power during combined drying might ensure good quality biological material dehydrated by the combined approach equivalent to the quality ensured by FD [41].

The present study was carried out with the following objectives- Drying of beetroot using an oven dryer under a temperature of 50℃; and a comparison of drying characteristics of beetroot dried in an oven dryer.

## 2 Methods and Materials

The drying experiments were performed in a laboratory oven dryer installed in the mechanical engineering lab at the University of Biskra. The type of oven dryer used is shown in Fig.1. The temperature was controlled by the temperature sensor automatically at 50 C°.

**Fig.1.** The oven dryer used in the experiments.

### *2.1 Drying tests*

Fresh beetroots (Beta vulgaris L.) were obtained from a vegetable market, cut into 3 shapes, and then used for the experiments.

The first shape: Square shape with **(5×5 cm)** and thickness **e = 5 mm**.

The second shape: A semi-circle shape with thickness **e = 5mm** and diameter **D = 5 mm**.

The third shape: Triangle shape with **(5×5×5 cm)** and thickness **e = 4 mm**.

The experiments were performed at **50 C°**. The weight loss of samples was measured using a weighing balance every **10 mn**. The drying process was stopped when the moisture ratio also stopped decreasing.

The measuring instruments used in the experiments are shown in the next figures.

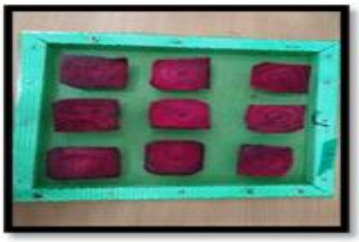

**Fig.2.** Square shape.

**Fig.3.** Semi-circle shape.

**Fig.4.** Triangle shape.

**Fig.5.** Thermometer-control (Model TPM-10).

**Fig.6.** Thermomètre Hygromètre Intérieur Numérique à Haute Précision.

**Fig.7.** Balance.

**Fig.8.** Thermometer type K.

## 3 Results and discussion

### 3.1 Drying products

Fig.9, 10, and 11 show the dried samples.

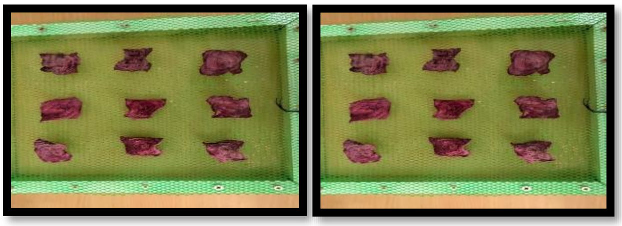

**Fig.9.** Square shape.

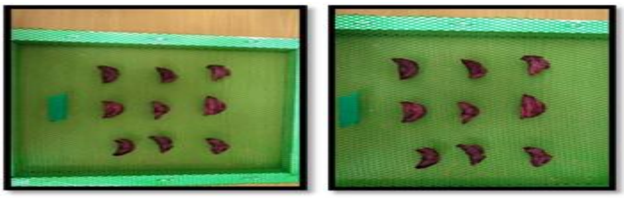

**Fig.10.** Semi-circle shape.

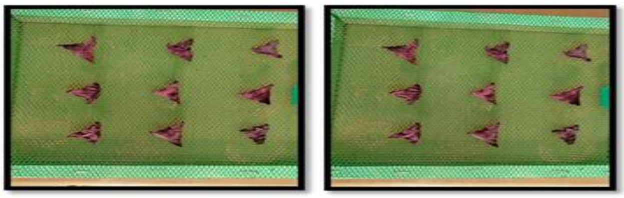

**Fig.11.** Triangle shape.

### 3.2 Drying curves

Fig.12 illustrates the different values of the temperature, such as the temperature of the drying chamber of the oven dryer, the ambient temperature, and the oven outlet temperature as a function of time. We found that the evolution of $T_{ch}$, $T_{\Delta T}$, and $T_{out}$ begins with perturbation until the moment which started with 75 min. We can say that this instability in the $T_{ch}$, $T_{\Delta T}$, and $T_{out}$ is because of the loss of heat during the process by opening and closing the door of the oven dryer for each test.

Fig.13 presents the variation of the power as a function of time. It can be seen that $P_{el}$ 's curve is constant all the time during the drying process at 42.5 w, while the evolution of the curves of $Q_{IT}$ and $Q_{eff}$ was parallel begins with an increase and then a decrease with perturbation, the $Q_{IT}$ curve decrease to approximate the power to zero at 350 min till 450 min. The $Q_{loss}$ begins with a constant value until 50 min, then a perturbation (increasing and decreasing) between 50 min and 200 min; after that, we can see an increase to approximate the power to the maximum value of almost 40 w.

Fig.14 shows the variation of the power as a function of time. As it represents the parallel of the evolution of the $Q_{et}$ and the $Q_{pt}$ during the drying process, they get the maximum value of 2 w for $Q_{et}$ and 2.25 w for $Q_{pt}$; the $Q_{et}$ curve to approximate the power to zero at a time of 312.5 min while the $Q_{pt}$ at a time of 350 min. The $Q_{vt}$ curve was in a low power all the time during the process (0 w); the evolution of the $Q_{bt}$ was perturbated; it reaches the maximum value of almost 7 w at 175 min and the minimum value of 0.25 w at 400 min.

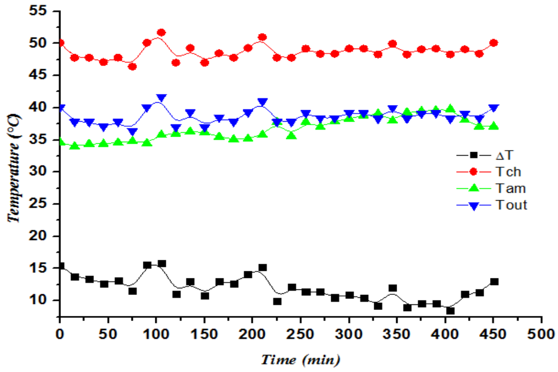


**Fig.12.** Variation of the temperature versus the drying process time.

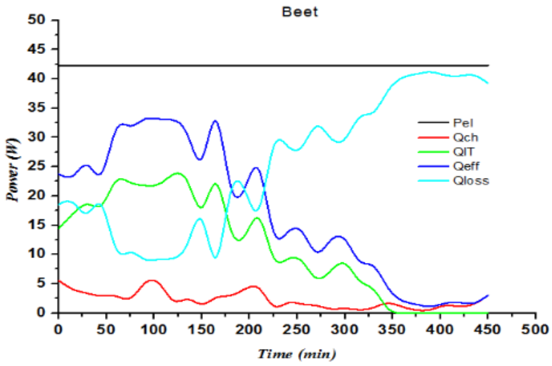


**Fig.13.** The product's power change versus the drying process time.

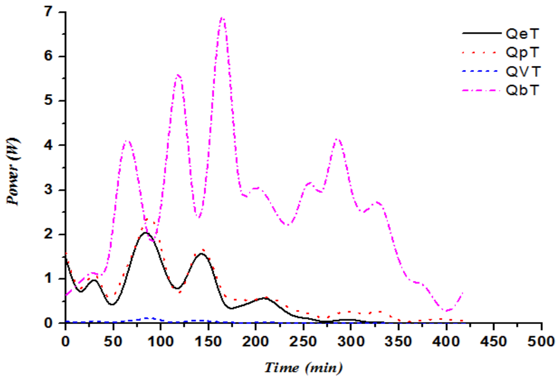


**Fig.14.** The change in power of the product versus the drying process time.

Fig.15 represents the variation of the temperature as a function of time, corresponding to three different shapes of the product of the beet. We remark that the temperature of the sliced beet where in perturbation in all the curves during the drying process, we notice that the temperature of the tested is closely related to the opening and closing access of the oven dryer, and taking out of the product every 10 min to take their weight, which made the temperature perturbed.

Fig.16 shows the variation of the temperature as a function of time. It is remarked that there is a perturbation in all the curves during the drying process because of the input and output procedure; it affects the product temperature, but it keeps the correct evolution of the curves. These different curves' evolution is perhaps due to the loss in temperature quantity in each system.

Fig.17 represents the variation of water vapor's mass as a function of time. It found that there is a decrease in the mass of water vapor with an increase in time during the process. That decrease in water's mass vapor connects with the increase in the product temperature. The curves of the semi-circle and the triangle have the same evolution, and this is due to the identical thicknesses

Fig.18 represents the variation of the stripped water mass as a function of time. It can be seen that $m_{w1}$ takes the high acceleration in evolution; it starts with 75 g until the value is fixed at zero in its estimated time of 325 min, and in the second setup we found the curve of the $m_{w3}$ begins with 450 min until it reaches the minimum value at the zero and fixed at a time of 275 min, and in the last, with low speed, the curve of $m_{w2}$ begins with 42.5 g and decreasing to stripped water mass to approximated zero at 325 min.

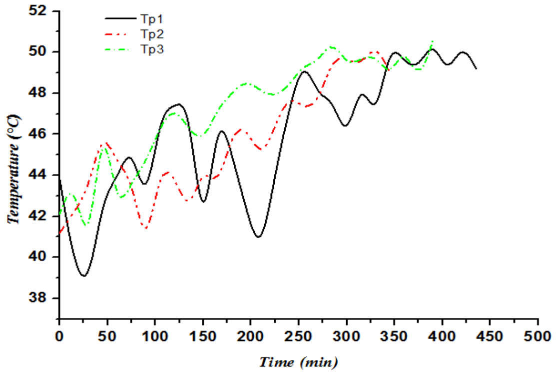


**Fig.15.** Variation of the product temperature versus the time for different thicknesses and shapes.

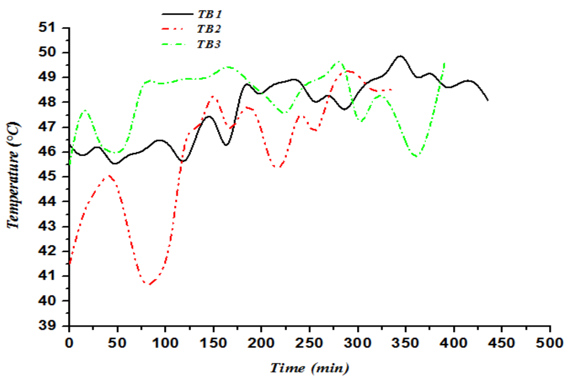


**Fig.16.** Variation of product temperature versus the drying process time.

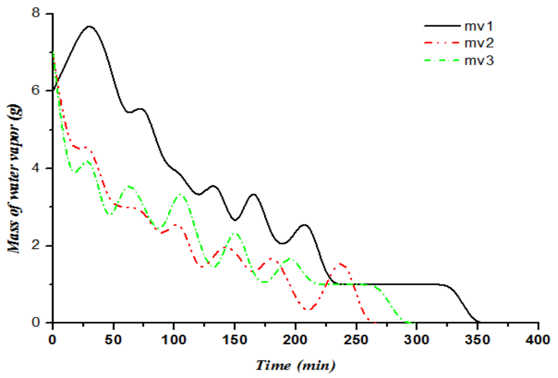


**Fig.17.** The change in mass of water vapor of the product versus the time of the drying process.

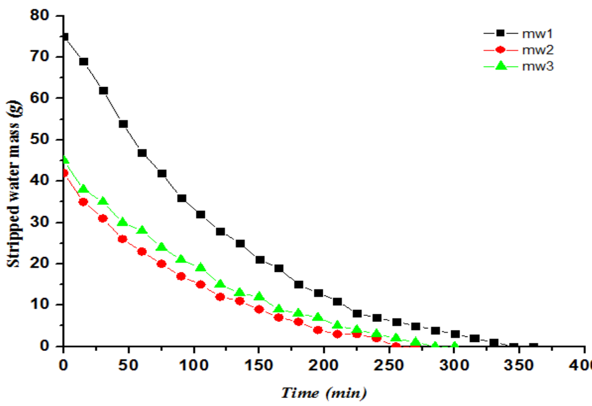


**Fig.18.** The change in the stripped water mass of the products versus the time of the drying process.

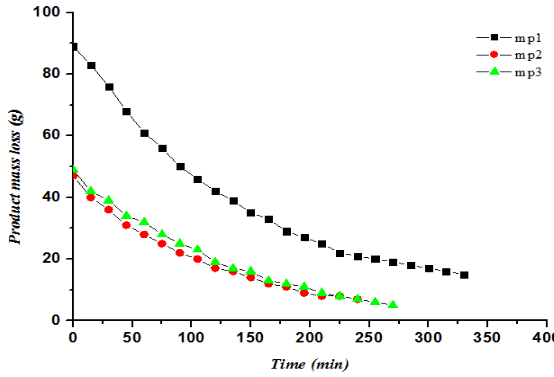


**Fig.19.** The change in the product mass loss during the time of the drying process.

Fig.19 shows the variability of the product mass as a function of time. We can remark that the same thing happened with the stripped water mass (fig 18); in which the $m_{p1}$ took the fastest decrease, while the two other curves of $m_{p2}$ and $m_{p3}$ were almost parallel with a low speed in the evolution, it means it is evident that the change in the product mass loss decreases with an increase in time.

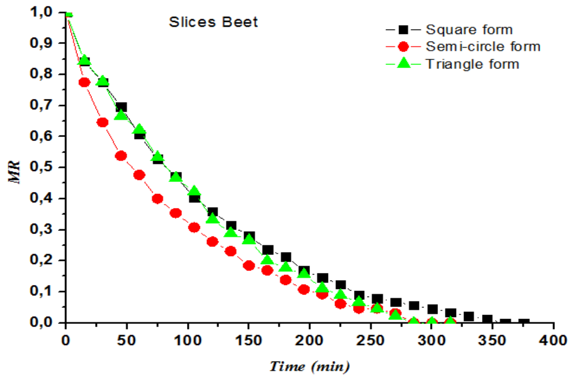


**Fig.20.** The moisture ratio versus drying time for different models and thicknesses.

Fig.20 shows the variation of the moisture ratio according to three different shapes of sliced beets. The results show that the curve of the MR takes the high acceleration in both curves of the square form and the triangle form until 0.025 kg. The square form continues with high acceleration while the triangle form continues with a low speed, and the last setup was the semi-circle, which had the lowest speed of the other two curves with an acceptable acceleration.

All the curves started with MR = 1 kg of water per kg of the dried product and decreased to MR approximately to zero, which means the product of the sliced beets with different shapes stopped extracting the water. The results give a different evolution of the moisture ratio taking into consideration the opening and closing of the door of the oven dryer, this part means the loss of the heat of the oven dryer.

## 4 Conclusion

The objective of this study was to dry three different shapes of beet using an oven dryer, and also to determine whether beetroot shape affects the process of drying or not by comparing the characteristics of the beetroot dried.

Oven drying can greatly reduce the drying time of food materials with internal resistance to mass transfer, beetroot (Beta vulgaris L.) has been dried in an oven drier, and the moisture is lost to a good extent, which means that an oven drier is an effective method for drying beetroot, improving that the thicker samples (the square shape and the semi-circle with 5mm to both) took a long time than the thin one (triangle shape with thickness of 4mm) and that mean that the loss in moisture ratio depends more on the thickness than the shape of the sample. The optimum temperature for drying beetroot is found to be 50°C in the oven drier. Finally, the drying rate decreases with the decrease in the moisture content. Future research on food drying will inevitably focus on lower energy costs, less reliance on fossil fuels, and reduced greenhouse gas emissions.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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