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Research Article

A Comparison of Drying Performances of Red and Green Apple Particles in a Tray Dryer

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Abstract

The green and the red apples were selected as drying materials in order to dry in a tray dryer for this study. They were washed with distilled water to wipe out all contaminants that can be affected negatively the results of experiment and they were chopped to the same dimensions. The length, width and thickness of each apple piece were adjusted as 65 mm, 37 mm and 12 mm, respectively. The apple particles were weighed with precision scales and they were grouped into 50 g, 100 g and 200 g. Then the particles were placed in the tray dryer for each set of experiments. Thereafter, drying process was carried out at different weights of red and green apple particles (mp), drying air velocity (U) and drying temperatures (Td). Herein, the moisture content (*MC*) is considered as the significant parameter in order to express the drying performance of drying materials. Moreover, energetic efficiency and normalized moisture content are compared with the empiric equation, which is proposed for the drying systems. The experimental study is performed with the range of 50 g ≤ mp ≤ 200 g, 18 % ≤ *MC* ≤ 614.29 %, 0.03 ≤ MR ≤ 1, 59 ^{o}C ≤ Td ≤ 99 ^{o}C and 0.992 m/s ≤ U ≤ 1.488 m/s. The result of this study is that the red apple particles have better drying performance at same conditions due to its physical properties when compared to green apple particles

Keywords: Food drying, Tray dryer, Red apple, Green apple, Moisture content.

Tepsili Bir Kurutucuda Kırmızı ve Yeşil Elma Parçacıklarının Kurutma Performanslarının Karşılaştırılması

Öz

Bu çalışmada, tepsili kurutucuda kurutulması için yeşil ve kırmızı elmalar kurutma malzemeleri olarak seçilmiştir. Kurutulacak katı gıdalar, deney sonuçlarını olumsuz yönde etkileyebilecek tüm kirletici maddelerden arındırılmak için damıtılmış su ile yıkanmış ve aynı boyutlarda kesilmiştir. Her bir elma parçasının uzunluğu, genişliği ve kalınlığı sırasıyla 65 mm, 37 mm ve 12 mm olarak ayarlanmıştır. Elma parçacıkları hassas terazilerle tartılarak 50 g, 100 g ve 200 g olarak gruplandırılmıştır. Daha sonra her deney seti için parçacıklar tepsili kurutucuya yerleştirilmiş, daha sonra, kurutma işlemi, kırmızı ve yeşil elma parçacıklarının (mp) farklı ağırlıklarında, kurutma hava hızında (U) ve kurutma sıcaklıklarında (Td) gerçekleştirilmiştir. Burada nem içeriği (*MC*), kurutma malzemelerinin kurutma performansını ifade etmek için önemli bir parametre olarak kabul edilmiştir. Ayrıca, enerji verimliliği ve normalleştirilmiş nem içeriği, kurutma sistemleri için önerilen ampirik denklem ile karşılaştırılmıştır. Deneysel çalışma 50 g ≤ mp ≤ 200 g, % 18 ≤ *MC* ≤ % 614.29, 0.03 ≤ *MR* ≤ 1, 59 ^{o}C ≤ Td ≤ 99 ^{o}C ve 0.992 m/s ≤ U ≤ 1.488 m/s aralığında gerçekleştirilmiştir. Bu çalışmanın sonucu, kırmızı elma parçacıklarının, yeşil elma parçacıklarına kıyasla fiziksel özellikleri nedeniyle aynı koşullarda daha iyi kurutma performansına sahip olmasıdır.

Anahtar Kelimeler: Gıda kurutma, Tepsili kurutucu, Kırmızı elma, Yeşil elma, Nem içeriği.

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1. Introduction

It is admitted that the drying process is one of the oldest and the fundamental method for preserving the food. The process can be basically defined as to remove the moisture from the solid food by using the heat energy. Fluidized bed, batch, tray and solar drying methods are commonly using for the operation in food drying processing facilities to decrease the moisture content of food. The main purposes of the process can be emphasized to reduce water activity, to prevent spoilage and to minimize the volume and weight of the food. With this aspect, the drying process is a necessity for agricultural areas due to develop the shelf life, decrease the packing cost, preserve flavor and nutritional value (Closas and Villanueva, 2014).

The drying process should be considered as a thermal system and it is examined with this respect. Therefore, as in all thermal systems, thermodynamic analysis is of great importance for the drying process (Tozlu, 2019). In recent years, the energy and exergy analyses are commonly used in the open literature in order to improve the efficiency of the all-thermal systems. The results are taken significant place for reducing inefficiencies in all engineering applications especially in thermodynamic fields. The energetic performance of food systems is widespread performed, on contrary to exergetic performance of these systems. Whereas, most studies showed that the energy analyses can be more considered as more valuable by combining with exergy analyses in the past decade. For this purpose, exergy analyses in addition to energy analyses should also be considered for food drying process just as in all thermal processes. Therefore, the recent studies in the open literature on the exergy analyses of food drying processes are summarized as follows:

It was concluded, in the study on green olive drying process in a tray dryer, that the exergy analyses of food systems can be handled in two sections, which are exergy analyses of various food processes in general and exergy analyses of food drying (Çolak and Hepbaşlı, 2007). A prediction for determining of required energy in solar dryer to drying process of mulberry was carried out by utilizing the thermodynamic relations. The exergy analyses of the system was evaluated in order to achieve the exergy losses in the solar drying system for the ranges of mass flow rate of 0.014 kg/s and 0.036 kg/s. It was stated that the the increase in mass flow rate was affected the energy usage ratio and the exergetic losses positively (Akbulut and Durmuş, 2010). Another solar drying study was handled experimentally to beef drying in order to estimate the related parameters. Herein, five drying models were carried out and they were observed taking into account the thermal relations. It was concluded that the dried beef in solar tunnel dryer has more merits that that of sun dried beef (Mewa et al. 2019). A batch type fluidized bed dryer was performed to analyze the performance of drying for the drying process. Wet corn and unshelled pistachio in different mass, temperature and air velocity, were dried in the system and the energy and the exergy analyses were carried out in that novel design system. The results were compared with the other fluidized bed dryer. The crucial parameters for the thermodynamic performance of bed dryers were claimed as particle mass and moisture content of the particle (Özahi and Demir, 2015). A tray drying process was performed for cassava starch in terms of energy utilization, and its ratio and efficiency, exergy inflow and outflow, exergy loss and exegetic efficiency. It was revealed that the exergy performance of a tray dryer system can be increased by increasing the drying air temperature (Aviara et al. 2014). The energy and the exergy analyses were carried out at different cabinet temperatures of onion pieces chopped at different thicknesses in a batch dryer. It was concluded that the enhancement on exergetic efficiency could be possible with the higher sustainability index, which was defined as the relationship between the input and the lost exergy of the system (Folayan et al. 2018).

Considering the open literature, there can be seen many studies on different types of drying systems. The energy and the exergy analyses performed in drying systems are extremely important in order to make the systems more efficient. As mentioned above, there are many dryer types such as fluidized bed, batch, tray and solar. In this study, drying process of chopped apple pieces of different weights in a tray dryer was performed.

2. Material and Method

2.1. Experimental setup

The experimental setup mainly consists of a radial fan, two plate heat exchangers, channel type resistance, drying trays and the base structures. In addition to this hardware, there are seven thermocouple and relative humidity sensors at the each point from A to G. There is a speed control unit in order to control the radial fan and also a touch operated screen for collecting data and controlling the drying process. The experimental test setup is shown in Figure 1.

2.2. Material and experimental procedure

The red and the green apples were selected as drying solid materials for the study and they were chopped to the same dimensions with the length, width and thickness of 65 mm, 37 mm and 12 mm, respectively. The cleaning procedure of apples was performed with distilled water to wipe out all contaminants that can affect negatively the results of experiment. The apple particles were weighed with precision scales and they were grouped into 50 g, 100 g and 200 g. After chopping the red and green apple pieces, they were placed on the tray and placed in the tray dryer. After this stage, the dryer was set to the desired drying air velocity and drying temperature by the speed control unit and channel type resistance. The apple particles grouped as 50 g, 100 g and 200 g were systematically dried in the tray dryer. Here, the same conditions were applied in each test set to carry out the experiments to the identical standard. By taking into account the low, the medium and the high drying air velocities the apples were dried until the moisture content of 25%, 20% and 18%, respectively. The weights of the apples were measured at 20 minutes intervals during the drying process. Thereafter, drying process was carried out at different weights of the red and the green apple particles (m_p), drying air velocity (U) and drying temperatures (T_d). In order to express the drying characteristics of drying materials significant parameters moisture content and moisture ratio should be taken into account. The moisture content (MC) and the moisture ratio (MR) were calculated as follows:

$$MC = \frac{W_w}{W_d} \quad (1)$$

$$MR = \frac{MC_t}{MC_i} \quad (2)$$

where, W_w, W_d, MC_t and MC_i represent the weight of water, weigh of dry material, moisture content at time and initial moisture content, respectively. The experimental study is performed with the range of 50 g $\leq m_p \leq$ 200 g, 18 % $\leq$ MC $\leq$ 614.29 %, 0.03 $\leq$ MR $\leq$ 1, 59 $^oC \leq T_d \leq$ 99 ^oC and 0.992 m/s $\leq$ U $\leq$ 1.488 m/s.

The importance of the energy utilization of drying is already emphasized previous section. According to the drying performance studies, an empirical equation is proposed as follows:

$$\eta_e = 0.0037 \exp^{10.46(MC_{(t)}/MC_i)} \quad (3)$$

where, η_e and $MC_{(t)}/MC_i$ represent the energetic efficiency and normalized moisture content, respectively. It can be used with a reasonable error and mean deviation for completely drying performances such as corn, pistachio and other solid foods. In this study, the equation is applied for the red and green apple particles for the drying temperatures of 59 ^oC and 79 ^oC when their mass and velocity are at 50 g and 0.992 m/s, respectively.

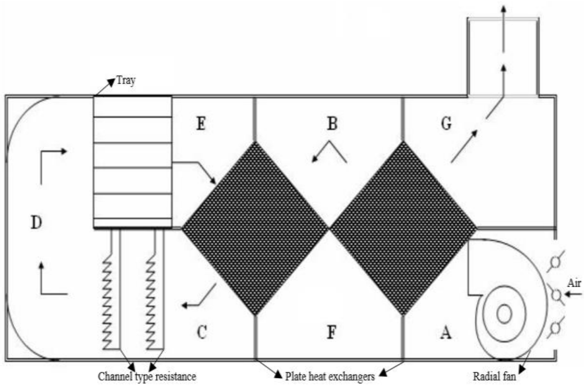


Figure 1. Experimental setup

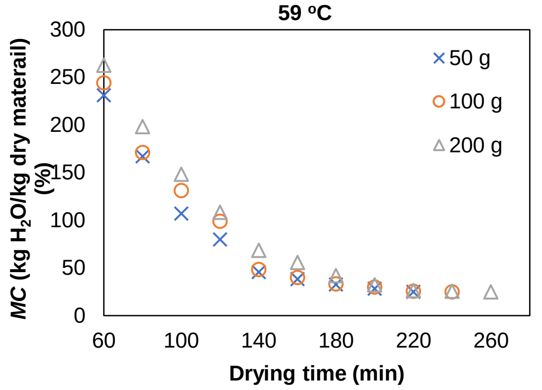
3. Results

The drying performances of red and green apple in tray dryer are obtained with the factors of the mass of apple particles, the drying air velocities, the drying temperatures. Due to this reason, all parameters are presented via related figures. In addition to this, energy efficiencies of drying are also presented.

The effect of particle mass with regards to moisture content in the matter of the elapsed drying time at constant U=0.992 m/s in the range of 59 $^oC \leq$ Td $\leq$ 99 ^oC for red and green apple are given in Figure 2 and Figure 3. The experiment continued until the moisture content of the apple particles decreased to 25% at U=0.992 m/s. Figure 4 and Figure 5 represent the elapsed drying time at constant U=1.24 m/s in the range of 59 $^oC \leq$ Td $\leq$ 99 ^oC for red and green apple. Herein, the drying is continued until moisture content comes to the 20 %. It can be seen the decrease in drying time when the drying air velocity is at U=1.488 m/s which are given in Figure 6 and Figure 7.

In figures from 2 to 7, it is clearly seen that the drying time of green apple particles are longer than that of red apple particles. This can be related to the physical properties of the apple such as particle sphericity, particle density and particle porosity. It is seen from the figures that the apple mass increases the duration of the experiment. Therefore, it can be said that the increases in the particle mass adversely affect the drying time.

When the figures from 2 to 7 are considered, it is clear that the moisture content decreases during the drying period. This phenomenon can be indicated as a nature of drying. The increase of the drying air velocity has a positive effect on the drying time. It is possible to see this from all the figures.



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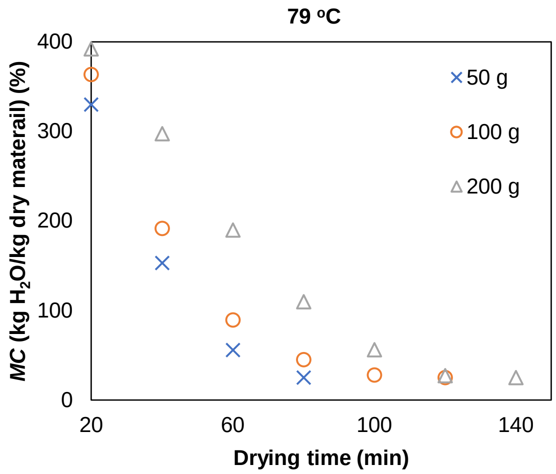

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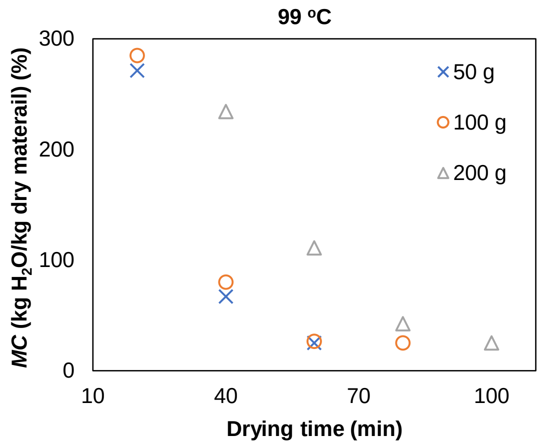
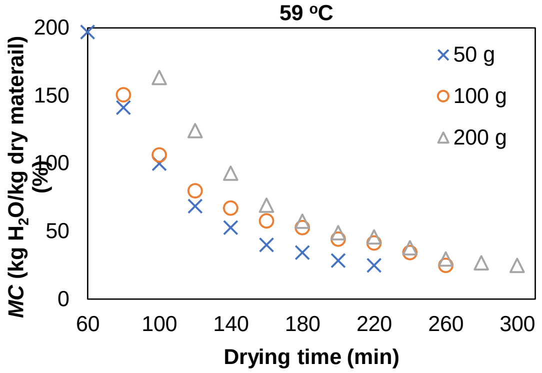


(c)

Figure 2. Effect of m_p on drying performance of red apple at U = 0.992 m/s



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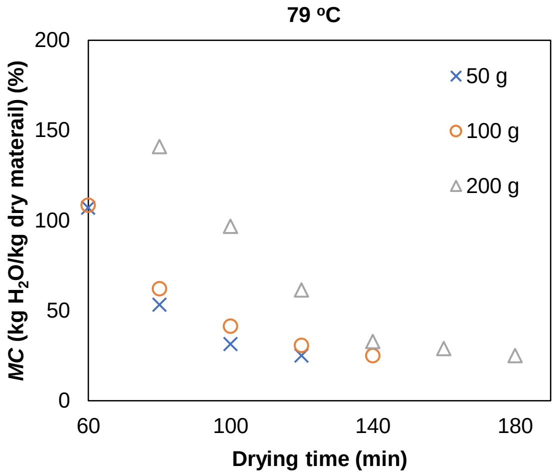

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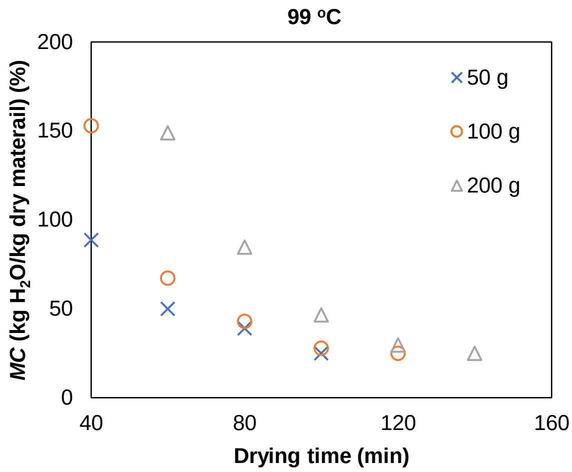

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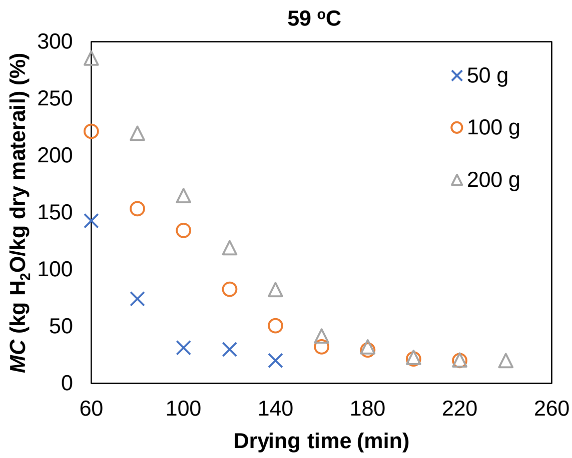
Figure 3. Effect of m_p on drying performance of green apple at U = 0.992 m/s



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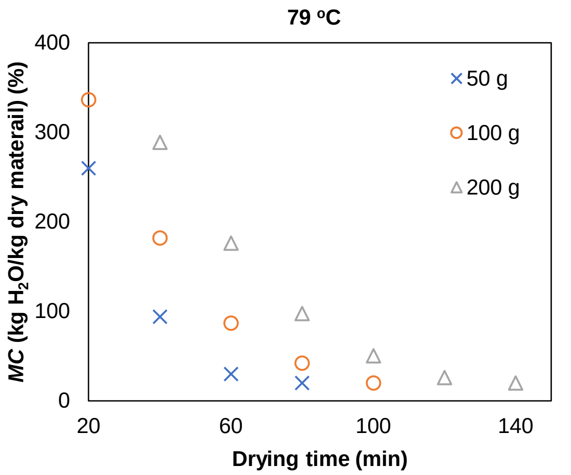

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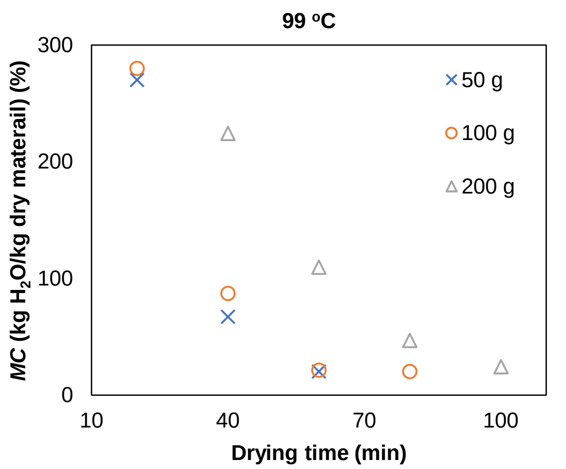

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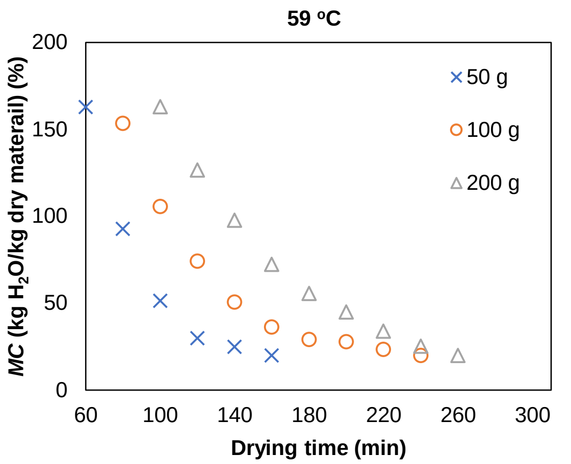
Figure 4. Effect of m_p on drying performance of red apple at U = 1.24 m/s



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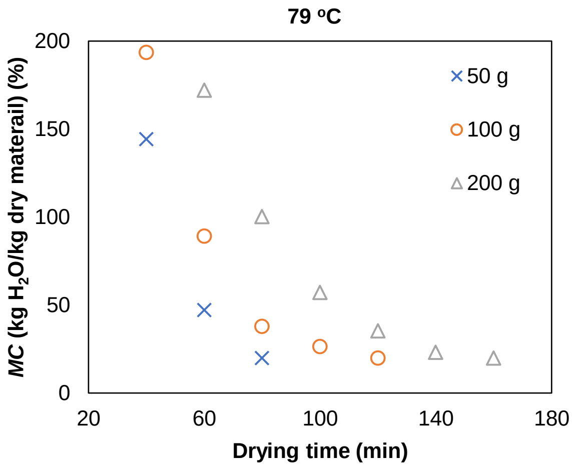

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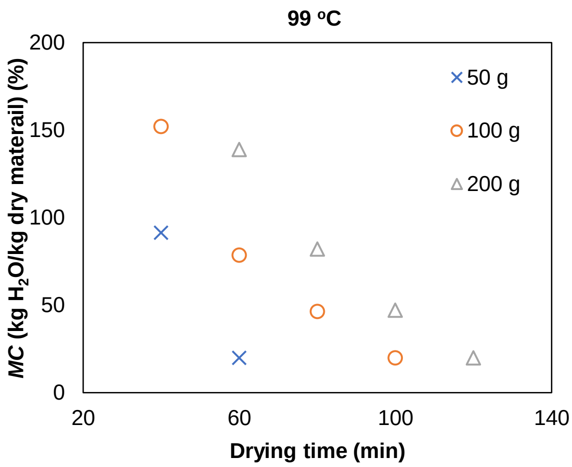

(c)

Figure 5. Effect of m_p on drying performance of green apple at U = 1.24 m/s

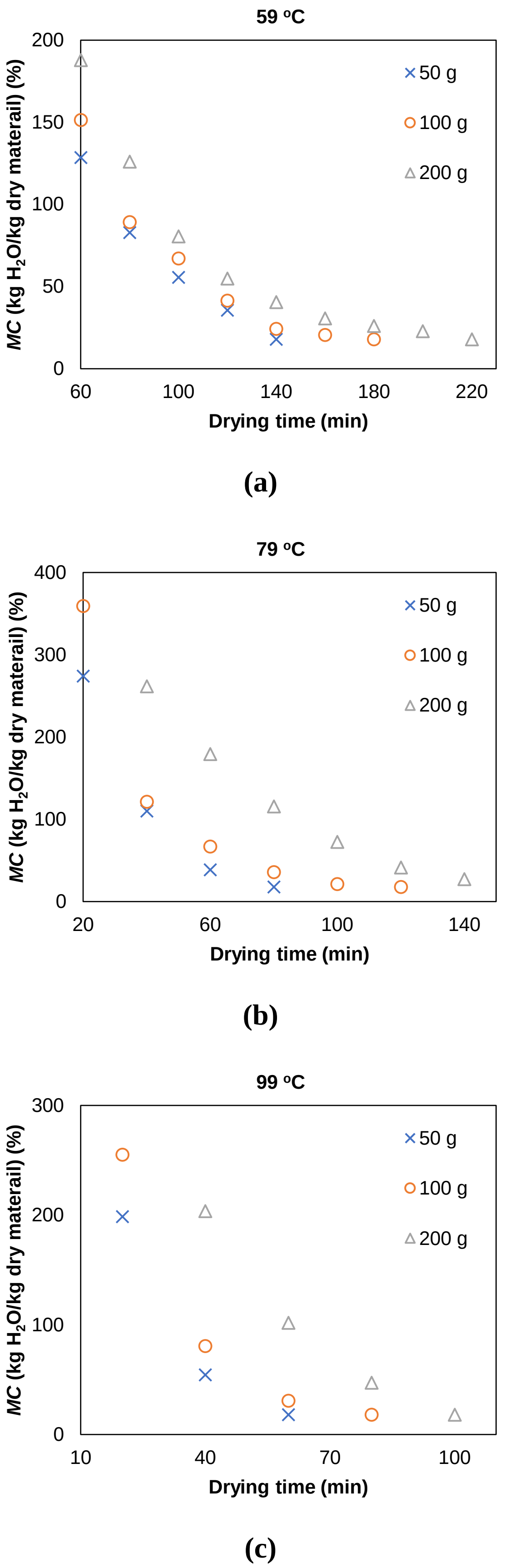

Figure 6. Effect of m_p on drying performance of red apple at U = 1.488 m/s

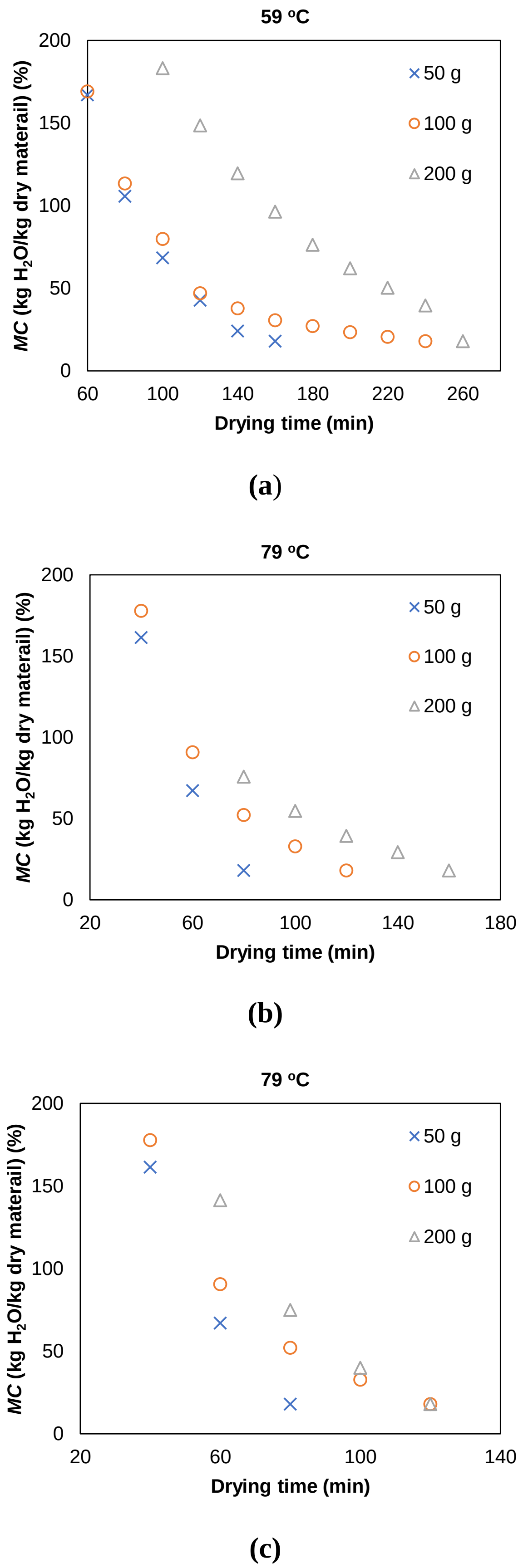

Figure 7. Effect of m_p on drying performance of green apple at U = 1.488 m/s

However, it should be emphasized that the effect of drying temperature on drying time more pronounced. For example, it is seen that the drying time of same weights green apple particles is shortened by about 40-60 minutes depending on the drying air velocity. However, the effect of increasing the drying temperature in the same case is seen to be about 120-160 minutes. Therefore, it should be emphasized that the drying temperature is a more effective parameter than the drying air speed.

The energetic efficiencies of 50 g red and green apple particles at T=59 °C are compared with available Eq. (3) in the literature. Figure 8 shows the results with respect to energetic performance and normalized moisture content. The maximum values of η_e for 50 g red and green apple particles at T=59 °C and U=0.992 m/s are found to be η_e=27.62% and η_e=23.06%, respectively. The variation of η_e with respect to $MC_{(t)}/MC_i$ for red apple drying is almost obeying with Eq. (3) with a mean deviation of ±7.44%. However, it is somehow different for green apple drying deviating from Eq. (3) with a mean deviation of ±22.74%.

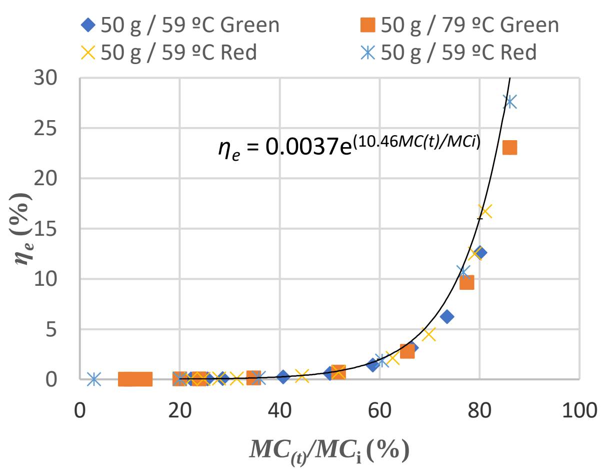

Figure 8. Comparison of energetic efficiencies

4. Conclusion

In this study, the red and the green apple particles with the mass of 50 g ≤ m_p ≤ 200 g are dried with the range of 59 °C ≤ T_d ≤ 99 °C drying air temperature and 0.992 m/s ≤ U ≤ 1.488 m/s drying air velocity. The results of the study are summarized as follows:

- The red and the green apples are selected as drying material for the study and they are chopped to the same dimensions. Then the drying performances of different types of apples are compared.
- In some studies, the effect of drying air velocity is found to be negligible when compared with the effect of drying air temperature. Contrary to this, the significant effect of drying air velocity on drying performance is observed, especially for the higher velocities.
- It is concluded that an increase of particle mass causes to increase of required drying time. This result is already expected. Herein, it can be stated as the importance of the study that the mass increases is not linearly increasing throughout the experiment.
- Required drying time decreases when both drying air temperature and drying air velocity are increased. But the drying air temperature is observed to be more significant than other parameters.
- It is found that more efficient drying process occurs at higher values of drying air temperature, drying air velocity and particle mass.
- The maximum values of η_e for 50 g red apple particles at T=59 °C and U=0.992 m/s is found to be η_e=27.62% with a mean deviation of ±7.44% with respect to Eq (3). On the other hand, the maximum value of η_e for green apple particles at same conditions is found to be η_e=23.06% with the mean deviation of ±22.74%.

- The results showed that the red apple particles have better drying performance at same conditions due to its physical properties when compared to green apple particles.

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