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Valorization of solar drying process in the production of dried Moroccan sweet cherries

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ABSTRACT

This study presents the convectional drying process of two types of Moroccan sweet cherry, namely, *Burlat* and *Van*. 40 g of cherries were taken, pitted, cut in two halves, and were dried using a partially indirect solar convective dryer, which has an area of 2.5 m^2. The thin-layer drying of sweet cherry were carried out in July 2017 at three air temperatures of 60, 70 and 80 °C and for two drying air flow rate 150 and 300 m^3/h. Moreover, the cherry fruits are sufficiently dried in the ranges between 34 and 40 °C of ambient air temperature, 17–27% of relative humidity, and 200–900 W/m^2 of solar radiation. The evolution of the moisture dry content and the drying rate as a function of drying time for different temperatures are shown graphically. Experience shows that as the air drying temperature increases the drying time decreases. During the experiments, pitted cherries were dried and the moisture content was decreased from 82.12 for *Burlat* and 85.45 for *Van* to 23 ± 3% (w.b). The drying temperature of 80 °C and air velocity of 300 m^3/h were the optimum values for cherry fruit drying in a minimum time of 240 min. The characteristic drying curve (CDC) applicable to both types of cherry has been established as a polynomial of order 3 in reduced moisture content.

1. Introduction

A growing body of research proves that fruits and vegetables are critical to promoting good health. In fact; they should be eaten throughout the year fresh or dried. Currently, up to 23 per cent of the most perishable ones are lost during their journey through the agri-food chain (Gustavsson et al., 2011) because they deteriorate: rotting, drying out, injuries due to mechanization during pick-up, packaging and transport, or because of the means of transport. Losses also occur during their shelf life.

In addition, in many developing countries, only a limited amount of products derived from fruit and vegetable are destined for local markets or for export due to lack of equipment and infrastructure.

In this context, our work is aimed at valorization of the Moroccan cherry fruits using a non destructive innovative preservation process integrating sustainable energy.

Cherries occupy the Cerasus subgenus within Prunus genous of Rosaceae family, subfamily Prunodeae. There are three main species of cherry fruits referenced in this section; sweet (*Prunus avium*), and tart or sour (*Prunus cerasus*), and ground (*Prunus fruticosa Pall*) cherries. Among the three species, of global trading importance are sweet and tart cherries (Chockchaisawasdee et al., 2016). They are currently grown in most of the countries with a mild and Mediterranean climate. Mature cherry fruit are composed of an edible thin protective exocarp (skin), an edible fleshy mesocarp (flesh), and an inedible stony endocarp (pit) surrounding the seed. Date of fall bloom is from 10 to 25 March, and the harvest period is from June to mid-July (Vursavuş et al., 2006; Wani et al., 2014). Turkey is the biggest sweet cherry producer in the world with 494,325 tons in 2013. The other countries producing cherries with their harvest amounts are USA with 301 205 tons, Iran with 200,000 tons, Italy with 131,175 tons and the Russian Federation with 78,000 tons. The cultivation of cherry in Morocco extends over an area of 1319 ha and produces about 14,000 annual tons (FAO, 2013). Sweet cherry is not only consumed fresh but also used to produce jam, jelly, stewed fruit, marmalade, syrup and several types of soft drinks (Ferretti et al., 2010; Wink, 2016) As a non-climacteric fruit, sweet cherries deteriorate rapidly after harvest. The limited life time does not exceed 21 days, which requires conservation to ensure their presence

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Nomenclature

CDC	characteristic drying curve
CDE	curve drying equation
Dv	drying volume flow rate (m^3/h)
d.b	dry basis
$\left(-\frac{dM}{dt}\right)_0$	initial drying rate, (kg water/(kg dry matter.min))
$\left(-\frac{dM}{dt}\right)_t$	the drying rate at any time of drying, (kg water/(kg dry matter.min))
f	dimensionless drying rate
M	Moisture content at any time of drying (% dry matter)
M_0	initial moisture content (% dry matter)
M_e	equilibrium moisture content (% dry matter)
M_f	final moisture content (kg water/kg dry matter)
MR	Moisture ratio
SE	standard error
r	correlation coefficient
w.b	weight basis

throughout the year (Wang et al., 2016; Wani et al., 2014). Drying is one of these preservation methods (Kowalski and Szadzińska, 2014). Dried fruits have a long self-life and therefore can provide a good alternative to fresh fruits, allowing the availability of out of season fruits (Singh et al., 2017).

Drying is the most common form of food preservation and extends the food self-life (Doymaz and İsmail, 2011). Drying (or dewatering) is a simple process of excess water (moisture) removal from a natural or industrial product in order to reach the standard specification moisture content (Belessiotis and Delyannis, 2011).

Reducing moisture content of foodstuff down to a certain level slows down the action of enzymes, bacteria, yeasts and molds. Thus food can be stored and preserved for long time without spoilage. Also, it brings about substantial reduction in weight and volume, minimizing packaging, storage and transportation costs (Hui and Sherkat, 2005).

This work aims to:

- Study the drying kinetics of two cherry cultivar in a convective solar dryer;
- Determine the effect of drying air temperature and the drying air flow rate on the drying kinetics of the cherry;
- Determine the characteristic drying curve of sweet cherry (CDC).

2. Experimental section

2.1. Sample preparation

The fruits of sweet cherry used for this experiment belongs to *Van* and *Burlat* cultivars, known hajjari and bigaro at Moroccan cultivars (A.OUKABLI, 2004). Maturation dates for Moroccan sweet cherry range from 25 May to 10 August, with the samples are harvested by hand in 17 to 21 July 2017 from Azzaden located in Imlil village (Marrakesh, Morocco). The fruits were transported in plastic bags and sorted visually for physical damage once in laboratory. The test samples were washed, drained and packed into vacuum bags in 250 g lots, about 30 fruits in each bag, and kept in refrigerator at 4 °C before drying. Generally, samples of uniform size selected. Initial moisture content of the fresh sweet cherry was determined by drying in an air convection oven at 105 °C for 24 h, performed in three replications for each cultivar (AFNOR NF V03-40).

2.2. Drying procedure

The fresh cherries are cut to create two halves and the pit was removed. The samples were chosen to have the same dimensions as much as possible; about 40 g of samples were used in each experiment. The main characteristics of cherry fruit are listed in Table 1. Before the start of any experiment, the dryer system was run for at least half an hour to achieve steady-state conditions. Experiments were performed at air temperatures of 60, 70 and 80 °C. At each temperature, two air flow rate values were used: 150 and 300 m^3/h. The samples are thinly distributed on the drying rack of the drying chamber (da Silva et al., 2012; Sarimeseli, 2011) to ensure homogeneity of diffusion during the drying operation. Previous studies have showed the product of the lower rack dries faster than that of the upper rack (Aghbashlo et al., 2008; Idlimam et al., 2008; Lahsasni et al., 2004). Thus, during all the tests, only the first rack is used. The heated air enters the drying cabinet below the trays and flowed up wards trough the samples. The auxiliary heater was used for controlling the drying air temperature in order to keep the drying air temperature constant. The variation of the wet mass of the product $M_h(t)$ as a function of time is determined by removing it from the drying cabinet for approximately 15–30 s using a digital weighing apparatus (± 0.1 g).

At the beginning of experiments, the weighing was made every 5 min, gradually increasing until 20 min towards the end of the experiment. All treatments were dried to 23.0 ± 3.0 kg H_2O/kg d.s. At the end of each experiment, we proceed by staving the product dried at 105 °C for 24 h to determine its dry mass M_d. Then, the moisture content of samples with respect to time is obtained by applying Eq. (1). The temperature and the relative humidity of air ambient at the entrance of the drying unit were measured by a thermo-hygrometer.

$$M(t) = \frac{M_h(t) - M_d}{M_d} \quad (1)$$

2.3. Experimental set up

The experimental apparatus used to study the kinetics of drying of cherry is a partially indirect solar convective dryer operating in forced convection (Fig. 1), installed in the laboratory of the "Higher Normal School, HNS" laboratory of Marrakesh. This is a system without storage and with total or partial recycling of air and it provides 80% of solar radiation. This is a real prototype dryer for small agricultural exploitation. The main parts of the dryer system consist of a solar air collector, an auxiliary heater, a circulation fan and a drying cabinet. The solar air collector had dimensions of 1 m by 2.5 m. A corrugated galvanised iron sheet painted black was used as an absorber plate for absorbing the incident solar radiation. It was oriented southward under the collector angle of 31°. This angle was fixed by the control foot. A glass and plastic sheet was used as a transparent cover for the air heater

Table 1
Some chemical properties of sweet cherry fruit samples.

Characteristics	*Burlat*	*Van*
Initial moisture of pitted cherry (% weight basis)	82.12 ± 1.44	85.45 ± 2.16
Fruit weight (g)	6.35 ± 0.73	6.80 ± 0.62
Stone weight (g)	0.23 ± 0.03	0.24 ± 0.04
Pedicel weight (g)	0.08 ± 0.01	0.09 ± 0.01
Diameter of fruit (mm)	19.69 ± 0.85	20.43 ± 0.77
Length of fruit (mm)	20.51 ± 1.01	21.39 ± 1.01
Thickness of fruit (mm)	7.8 ± 0.93	8.46 ± 0.81
Sphericity (%)	92.2 ± 0.02	85.27 ± 0.82
Length of pedicel (mm)	27.84 ± 0.04	33.25 ± 0.04
Volume (cm^3)	4.61 ± 0.55	5.37 ± 0.37
Surface area (cm^2)	13.13 ± 1.12	15.29 ± 0.95

Values are means ± standard deviation (n = 3).

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