THE EFFECT OF DRYING AIR TEMPERATURE ON THE KINETICS AND QUALITY OF TABLE BEET (BETA VULGARIS)

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https://doi.org/10.5281/zenodo.19381284

Annotation. This study investigated the drying of table beetroot *(Beta vulgaris)* using hot air at temperatures of 65, 70, and 75 °C. Key physicochemical characteristics of the raw material were determined, including moisture content, water activity, pH, and soluble solids content. The kinetics of moisture removal, changes in water activity, and the effect of temperature on product quality were studied. It was found that increasing air temperature leads to an increase in the drying rate and a decrease in the drying time. However, at higher temperatures, increased quality degradation is observed, including changes in color characteristics and the destruction of vitamin C. The obtained results allow us to determine optimal drying conditions that ensure a balance between process intensity and product quality preservation.

Introduction

Dehydration is a method of processing and preserving food products. It involves removing some of the moisture from the product, preventing spoilage. This property is essential for canning. Drying extends the shelf life of beets and enables their transportation to distant markets. It also allows for off-season use, resulting in a higher price. Dehydrated beets retain a significant portion of their original nutritional value when properly processed [1].

There are various drying methods and their modifications. The choice of method depends on the type of product to be dehydrated, the required quality level, and the economic cost. Drying methods using air convection include drum (roller) and vacuum dryers. Some are used for liquid products, while others are used for solid materials. Each method has various variations tailored to the production volume and characteristics of the final product. Currently, hot air drying remains the most widely used dehydration method in the food and chemical industries. However, before studying the drying process and assessing its effectiveness, it is necessary to determine the equilibrium moisture content of the product, which depends on ambient air conditions. This requires knowledge of the desorption isotherm, which can be described by various mathematical

models. Equations with parameters that have physical meaning are the most preferable [2].

The relevance of this study stems from the growing interest in developing energy-efficient and resource-saving technologies for processing plant materials. Drying, as one of the most common preservation methods, significantly reduces product loss and ensures long-term shelf life. Selecting optimal process conditions to preserve the product's biologically active substances and organoleptic characteristics is particularly important. Studying the drying kinetics of beetroot allows for a more accurate description of the heat and mass transfer process [3].

Drying vegetables at high temperatures affects the organoleptic properties of the product and its nutritional value. During the process, the texture, color, density, porosity, and adsorption characteristics of the material change and hardening and shrinkage phenomena are also observed. Therefore, drying temperature is an important parameter taken into account in kinetic studies. Although increasing the temperature accelerates the process, quality losses are not always compensated by a reduction in processing time. Krokida et al. studied the influence of process parameters such as air temperature and relative humidity, air flow velocity, and particle size on the vegetable drying process using empirical kinetic models [4].

Materials and methods

The present study aimed to evaluate the process of drying table beet (Beta vulgaris) with hot air and the effect of air temperature on the kinetic parameters of drying [5]. The drying process of table beet was carried out in accordance with the scheme presented in Fig. 1.

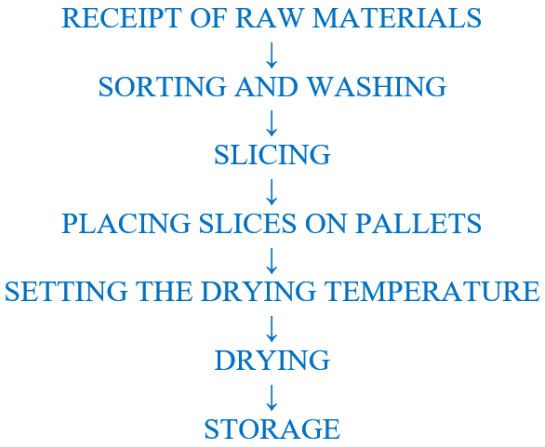


Figure 1. Schematic diagram of the process for evaluating the efficiency of drying table beetroot *(Beta vulgaris)* with hot air

Results and Discussion

Table 1 presents the experimental moisture content, soluble solids (°Brix), liquid fraction, water activity (aw), and pH values for the various batches of fresh beet used in this study. The obtained values are within the range typical for this type of raw material [6].

Table 1. Physicochemical characteristics of table beet *(Beta vulgaris)* used in the study

Indicator	Meaning
Moisture (g water/g sample)	0.87±0.01
Soluble solids (g/g)	0.10±0.02
°Brix (g dissolved solids/100 g sample)	9.5±1.0
Water activity (aw)	0.97±0.01
pH	5.8±0.3
Vitamin C (mg/100 g sample)	4.5±0.5

Effect of drying conditions on drying rate. As specified in the method, each drying process was carried out continuously. Moisture content in the samples throughout the process was determined using the mass balance method, based on initial values (Table 2).

Table 2. Effect of air temperature on the drying process of table beetroot (Beta vulgaris)

Time, h	65°C (humidity, g water/g dry matter)	A_w	70 °C (humidity, g water/g dry matter)	A_w	75 °C (humidity, g water/g dry matter)	A_w
0	5.800	0.970	5.800	0.970	5.800	0.970
1	2.400	0.920	2.000	0.900	1.700	0.880
2	1.200	0.850	0.950	0.820	0.700	0.780
3	0.600	0.780	0.500	0.740	0.350	0.650
4	0.350	0.700	0.280	0.660	0.180	0.550
5	0.220	0.650	0.180	0.600	0.100	0.450
6	0.150	0.600	0.120	0.550	0.070	0.380
7	0.100	0.550	0.080	0.500	0.050	0.320

The reproducibility of the curves was quite high, as demonstrated by the low variability of the parameters obtained for each mode, as shown below (Figure 2).

Figure 2 shows that, as the air temperature increases, moisture removal increases in a shorter time during the drying process, indicating an increase in drying rate.

With increasing air temperature, the slope of the beetroot dehydration curves increases, resulting in a reduction in drying time (Fig. 2). This is due to an increase in product temperature and moisture diffusion coefficient, as well as a decrease in relative humidity, which increases the air's moisture capacity and intensifies the mass transfer process [7].

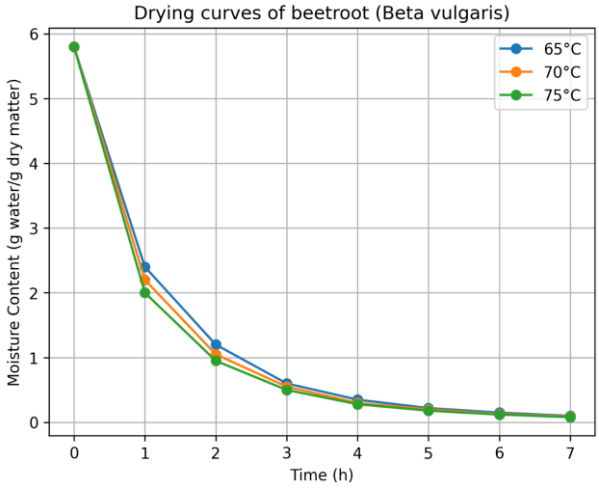


Figure 2. Drying curves of beetroot (*Beta vulgaris*) at different air temperatures

A period of constant drying rate is observed at the initial stage of the process and is associated with moisture evaporation from the surface, during which the rate of moisture supply from the inner layers is comparable to the rate of its removal [8].

An important indicator of process efficiency is the time it takes to reach the desired final moisture content. Increasing the air temperature, as well as the use of pre-treatment methods, including microwave treatment, can significantly reduce the drying time [9].

As shown in Fig. 3, water activity decreases more rapidly with increasing air temperature, especially at 90°C, where the sharpest decrease is observed in the first 3 hours, after which the changes become less pronounced [10].

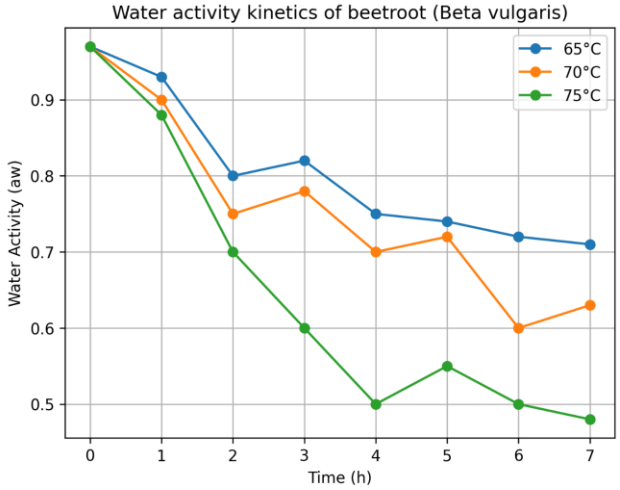


Figure 3. Kinetics of water activity change of beetroot (*Beta vulgaris*) during drying at different air temperatures

Conclusions. Increasing the drying air temperature from 65 to 75°C increases the rate of moisture removal and reduces the drying time of red beets. Drying kinetics show that the most intense moisture removal occurs during the initial period of the process, regardless of the temperature. Water activity decreases more rapidly at higher temperatures, which contributes to increased product stability during storage. It has been established that increasing temperature accelerates quality degradation processes, including product darkening and a decrease in vitamin C content. The optimal drying range is 65–70°C, which achieves a compromise between process speed and preservation of finished product quality.

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