ENERGETIC ANALYSIS OF TUBERS DRYING

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Abstract

In this study the empirical analysis of convective and microwave drying of tubers is presented. The final purposes of experiments were to reduce the energy consumption of drying process while keeping the appropriate quality of dried material. During the experiment carrot and potato were used as samples.

Experiments proved that tubers show different drying parameters, depending on their morphological compositions. As tests proved in the case of microwave it can be supposed that an intensive moisture movement is established in the vascular systems even in the end of drying process and these phenomena give a good chance to apply a pertinent combination of convective and microwave energy that can result a well efficient drying process and end product of good quality.

Introduction

The drying is one of the most energy-intensive unit operations in treating agricultural products. At the same time the influence of drying on the final product quality and on the prime cost is dominant (Beke, Vas, 1994).

The drying regime of agricultural product is more complicated chemicophysical process as usual, because in this case drying materials are living organisms in which with parallel the dewatering process morphologically determined vital functions take place. As a result of the thermal drying the significant parts of natural flavors are off, shrinkage caused by drying deforms the final product and the cell walls become rigid. Under microwave conditions drying materials as excellent absorbents show special feature and their overdrying can be occurred (Bengston, Risman, 1971). For biological materials we usually cannot calculate with inner homogenous moisture and temperature field (Beke, Ludányi, 2007).

More than 95% of drying equipment used nowadays in the agriculture operates by convective method. As a possible non-convective drying technology the microwave drying can be taken into consideration because in the asymptotically falling drying rate period the microwave dewatering method becomes more economical and an efficient drying technology can be obtained.

Equipment and concept of experiments

For analysis of the convective drying process special laboratory equipment was developed (Beke, 2004). The features of the apparatus gave possibility to measure the input and output temperature, the velocity and the relative humidity of drying rate, as well as the weight of the drying sample. The moisture content of material was determined according to the relevant ASAE standard.

During microwave drying – to serve a nearly homogeneous microwave field – a resonator of basic mode was used as the test chamber in which waves are reflected onto the so-called Brewster-angle (Beke, Ludányi, 2007).

As the typical parameter of convective experiments the inlet air temperature was 80 °C and 100 °C explicitly, while the velocity of the incoming drying air was fixed on 0.4 and 0,8 m/s.

The incident microwave power was Pi=1000 W with a frequency of 2.45 GHz.

As samples, potato, parsley root and carrot were used. In the case of root drying slices with thickness of 10 mm were prepared. The dried slices were chopped into small cube-shaped blocks with measure of 5x5x5 mm. In the lengthwise of the root 6 measuring cross-sections were formed.

For the analysis of the relationship between the moisture content and the energy consumption of the drying process – as a characteristic parameter – the relative energy consumption was created. By measuring the input and output temperatures and the airflow rate the utilized convective heat energy could be calculated. Similarly, by knowing the dissipated performance the temporary absorbed microwave energy could be determined. The relative energy consumption was given as the quotient of the temporary and the minimum values of the energy consumption measured during the same experiment.

Results and discussion

When tubers are dried by convective method during the process of falling drying rate the peel thickness of samples more and more increases, the pores on the surface gradually narrow that greatly hinder the dewatering process.

In the case of microwave dehydration similar drying rate curves to those of convective drying are obtained but they show significantly more rapidly increasing characteristics.

In this case the falling drying rate period is divided into a linear and an asymptotical interval. The biological construction of the drying material does not support the surface energy- and mass transport. Specific drying rate curves of some tubers can be seen in Figure 1 for the cases of convective and microwave drying. It is evident that during microwave drying the incident energy is better utilized.

As results of analysis for the energy consumption of convective drying the following equation was derived to describe the relationship between the relative energy consumption (qrc) and the initial moisture content of drying material (X):

$$q_{rc} = e^{a_K + b_K \ln X} \quad (1)$$

As a result of similar analysis to that of the convective method the energy consumption of microwave drying – as a function of the moisture content – can be described by the following equation:

$$q_{rm} = a_M - b_M \ln X \quad (2)$$

The „a" and „b" constants in Equations (1) and (2) were determined by regression analysis, henceforth its values can be seen in Table 1.

Table 1. Values of constants in Equation (1) and (2)and the Ministry of Environment on the basis of transmission)

Drying material	a_K	$-b_K$	$-R_K$	a_M	$-b_M$	$-R_M$
Potato	-0.144	1.411	0.996	0.942	1.185	0.986
Parsley root	0.284	1.527	0.987	1.344	1.454	0.991
Carrot	0.272	1.535	0.965	1.378	1.499	0.940

By taking the mean energy consumption in the constant drying rate interval as unit, dimensionless energy consumption can be created for the falling rate period.

As the Equation 2 and Figure 2b prove under microwave conditions the energy consumption as a function of the moisture content shows a purely exponential trend.

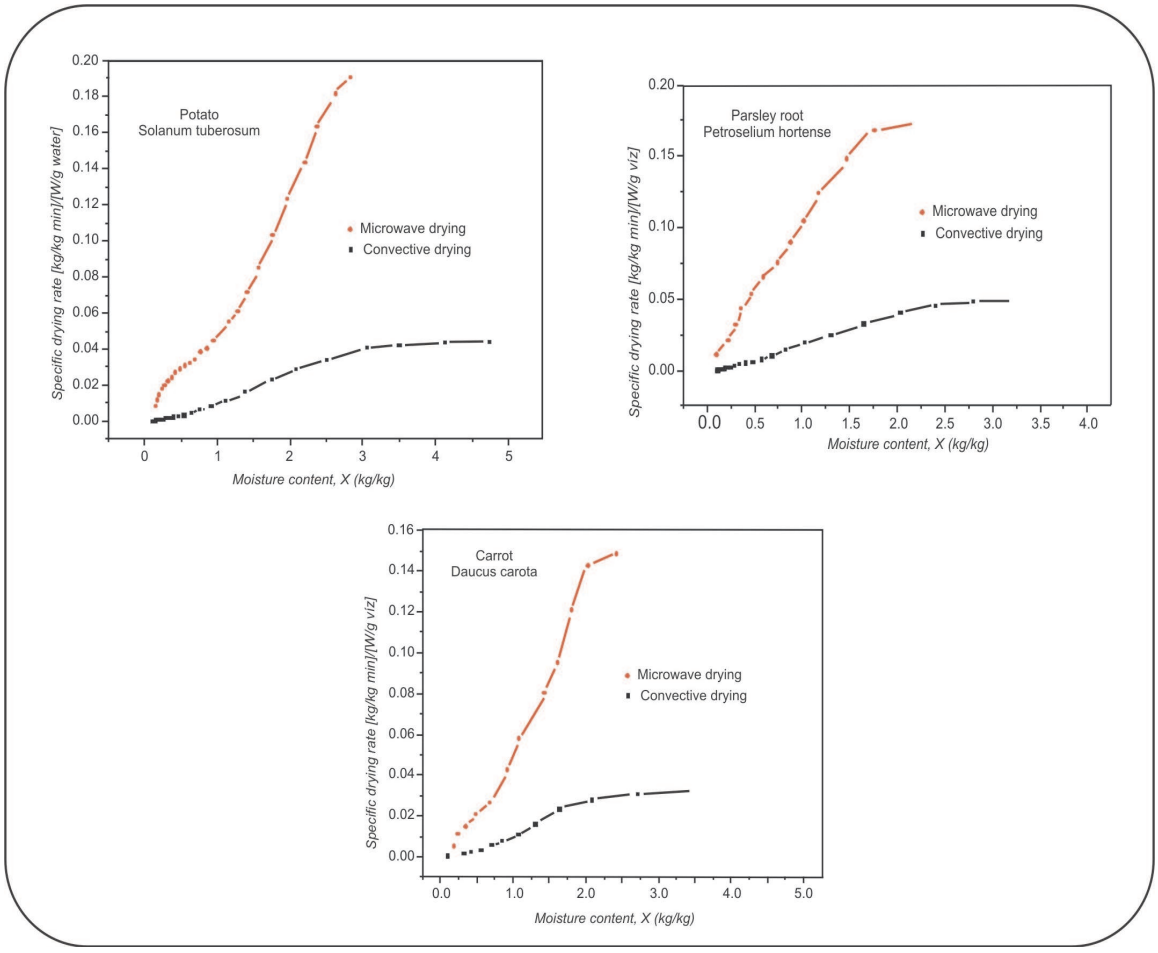

Figure 1. Drying rates of tubers, caused by 1 W/g water incident energy

On the one hand we can realize that the microwave drying needs less entering energy by at least one order of magnitude (in aspect of the pure energy and mass transport). On the other hand significant differences are demonstrable in the energy consumption of types of vegetables that have morphological reasons. For instance the xylem-type built-up does not support the moisture flow in the cross direction. The longitudinal xylem systems of tubers support the longitudinal moisture flow during drying.

By following up the same procedure but in convective conditions it turns up that in this case the exponential character of the relative energy consumption is much powerful (Equation 1, Figure 2a).

Conclusions

In the falling drying rate period – when microwave energy is used for drying – the energy consumption as a function of the moisture content shows a purely exponential trend. At the same time in convective conditions this exponential character of the relative energy consumption is much powerful.

From the point when the drying rate curve enters the asymptotically decreasing water loss rate interval the energy consumption of convective dehydration increases dramatically and exceeds by an order of magnitude that of the microwave dewatering process.

Under these conditions using microwave energy become more favorable from energetic and also economical point of view. Combining the two drying methods an efficient drying technology and an end product of excellent quality can be obtained.

References

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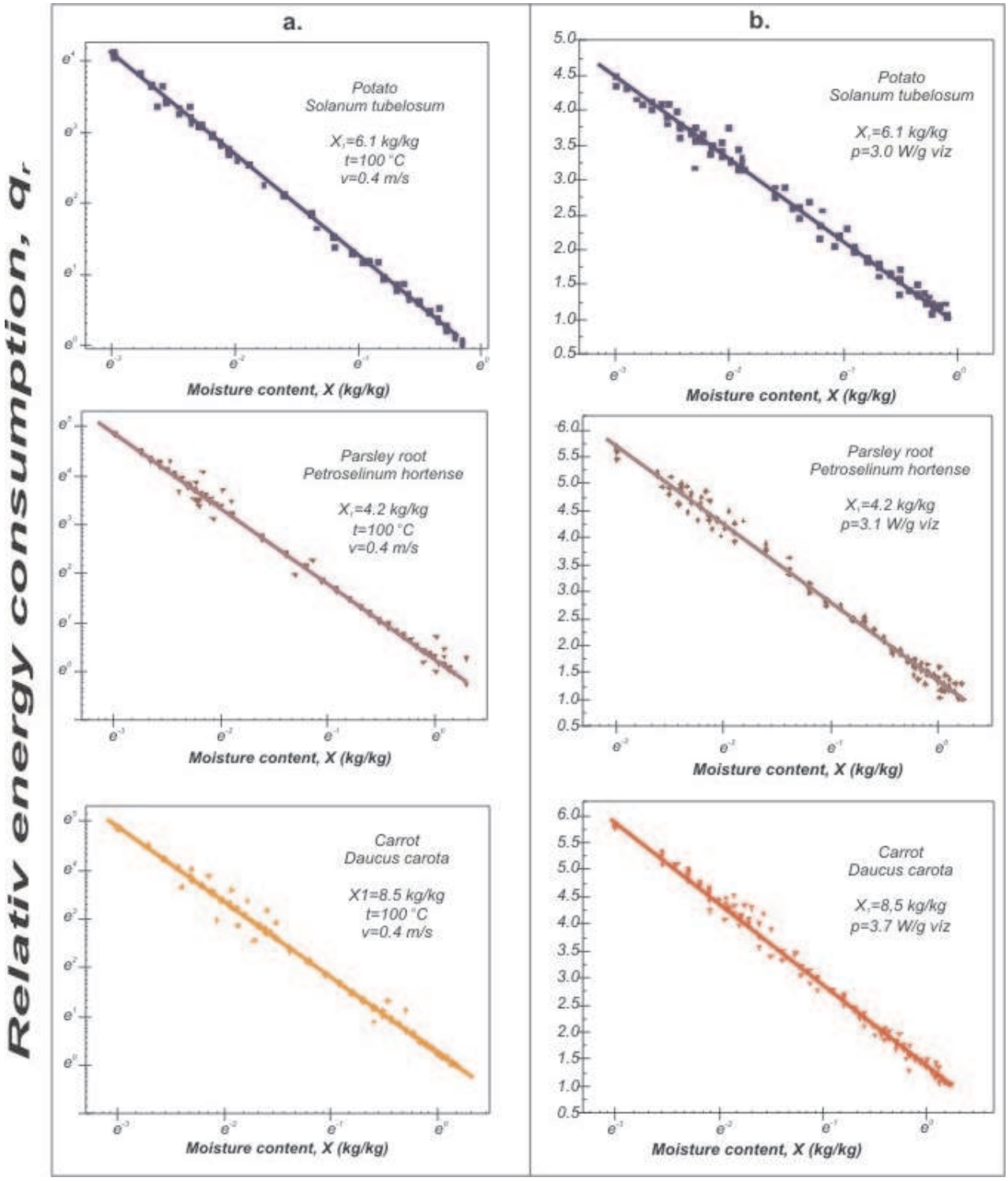

Figure 2. Energy consumption of drying tubers as a function of moisture content in convective (a) and microwave(b) conditions