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INFLUENCE OF BLANCHING AND CONVECTIVE DRYING CONDITIONS OF PARSLEY ON PROCESS ENERGY CONSUMPTION

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Summary. The aim of this study was to evaluate the influence of temperature (40, 50, 60, 70°C), flow velocity of the drying air (0,5 i 1 ms^{-1}) and water blanching (3 min) on the specific energy during convective drying of parsley. The total process energy was also evaluated. The results showed that an increase of drying air temperature from 40 to 70°C caused a decrease of the total process energy by about 43% (1 $ms^{-1}s$) and 31% (0,5 ms^{-1}) for non-blanching parsley, and about 52% (1 ms^{-1}), and 42% (0,5 ms^{-1}) for blanching material. For each drying temperature the total drying energy was lower in the case of the flow velocity 1.0 $ms^{-1}$and decreased after blanching. The lowest average total drying energy (10.5 $MJkg^{-1}$) was obtained for blanched parsley dried at the temperature of 70°C, and for the air flow velocity of 1.0 ms^{-1}.

Key words: convection-drying, energy consumption, parsley.

Nomenclature:

e - specific drying energy [$MJ·h^{-1}·kg^{-1}$],
E - total drying energy [$MJ·kg^{-1}$],
T - temperature [°C].

INTRODUCTION

Vegetables are a necessary component of a healthy diet and should be consumed every day, but their seasonal occurrence and limit shelf life cause a necessity of using adequate food preservation methods [Pabis 2007, Jech et al. 2006].

The freeze drying is one of the best methods of food preservation. During this process the physical and chemical changes occurring in raw materials are minimized [Lis T. and Lis H. 1999, Lisowa et al. 1999, King 1980, Kawala et al. 1993, Ratti 2001, Rudy 2009]. However, the energy consumption during freeze drying is very high, which limits the application of this drying method. Therefore, convective drying is commonly chosen in food industry because of its simplicity and low cost [Nindo et al. 2003].

The minimization of energy requirements during drying depends on adequate methods of raw material preparation and selection of the optimum process parameters [Benali, Amazouz 2006, Flink 1977, Koyuncu et al. 2004, Tippayawong et al. 2009]. Among many methods of pre-reatment, blanching is among the most common ones. It is usually performed prior to drying, to inactivate enzymes responsible for various undesirable enzymatic reactions. Blanching also helps to remove the air from the intercellular spaces [Postolski 1987, Klimczak and Irzyniec 1994, Zadernowski and Oszmiański 1994]. Moreover, blanching can help increase the drying rate, hence reducing the drying time [Skorupska 1998, Depta and Lis 2001, Szarycz et al. 2003, Severini et al., 2005] and thus the energy consumption decreases. Due to the steadily rising costs of energy, the investigations of drying energy consumption are constantly required.

MATERIALS AND METHODS

The aim of this study was to evaluate the influence of water blanching, temperature and flow velocity of the drying air on the energy consumption during convective drying of parsley.

The investigations were performed for two drying flow velocities, namely 0.3 and 1 ms^{-1}, at the temperature of 40, 50, 60, and 70ºC. The material for investigations was parsley (cv. Berlińska). Before drying, the material was cut into 10 mm cubes and blanched in water bath at the temperature of 95°C for 3 min. The second part of material was not blanched (control sample). The process of convection drying was continued until the mass of the sample reached the constant moisture (12% w.b.) The convection dryer`s load was 12 kgm^{-2}. The energy expenditure on the drying process was calculated at hourly intervals.

The convection drying was conducted using a vertical air-flow dryer (Fig. 1). The heating assembly of the dryer consisted of three heating elements and, more specifically, of heaters in chamotte casings, with a total strength of 6.9 kW. One of these heaters was connected into the circulation system of the temperature regulator. The axial ventilator, powered by an electric engine with a multi-stage regulation of rotation, ensured the air flow.

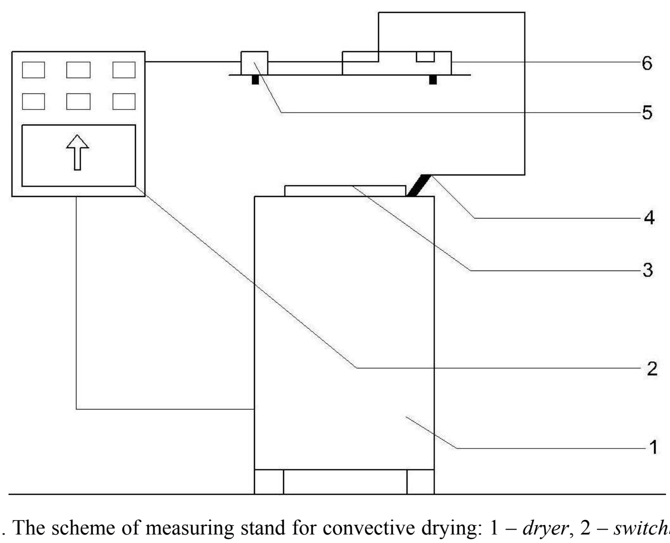

Fig. 1. The scheme of measuring stand for convective drying: 1 – *dryer*, 2 – *switchboard*, 3 – *tray*, 4 – *contact thermometer*, 5 – *contactor*, 6 – *stabilizer*

The measuring stand was also equipped with meter of electric power. The specific drying energy (e) was calculated using the numerical integration method changes of power consumption as a function of time, related to the mass of the processed material, and expressed in $MJ \cdot h^{-1} \cdot kg^{-1}$. The total energy distributed to the convection dryers (E) constituted the sum of energy inputs during the whole period, and was expressed in $MJ \cdot h^{-1}$. The measurements were replicated 5 times. The obtained data were further subjected to the statistical analysis and the consequent evaluations were analyzed with the variance analysis. The linear regression analysis was also carried out on these data. All the statistical tests were carried out at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The significantly longest average drying time of parsley was noted for unblanched raw material and dried in the temperature of 40°C, and for the air flow velocity 0,5 ms^{-1}. The use of blanching and an increase of drying air flow velocity reduced the drying time for each used temperature level (Fig. 2).

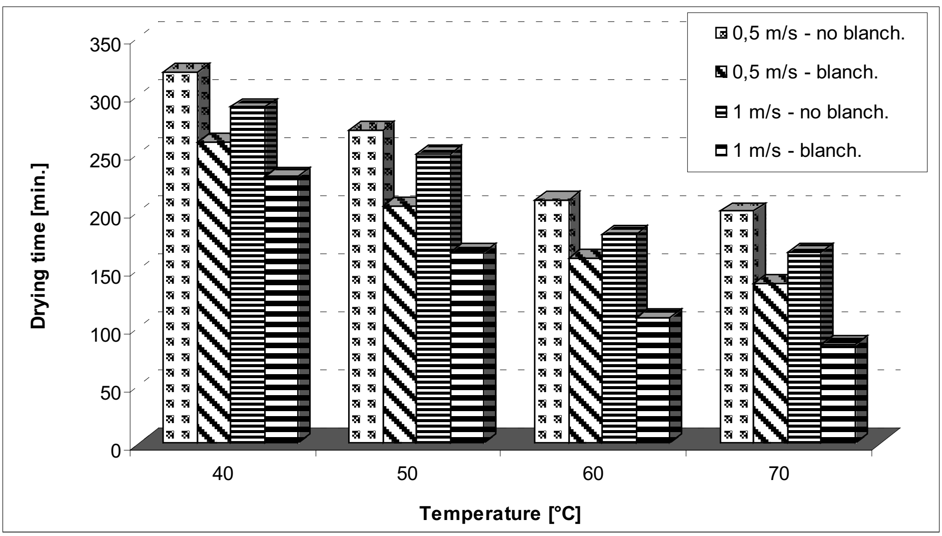

Fig. 2. The time of convective drying

The average values of specific drying energy (e) in the consecutive stages of parsley convective drying and in the relation to drying temperature and air flow velocity, and by using blanching were presented in Figures 3-6. For each drying temperature, the inverse relationships were observed between the drying time and specific drying energy consumption. These relationships were described by the linear regression equations (Tables 1-4).

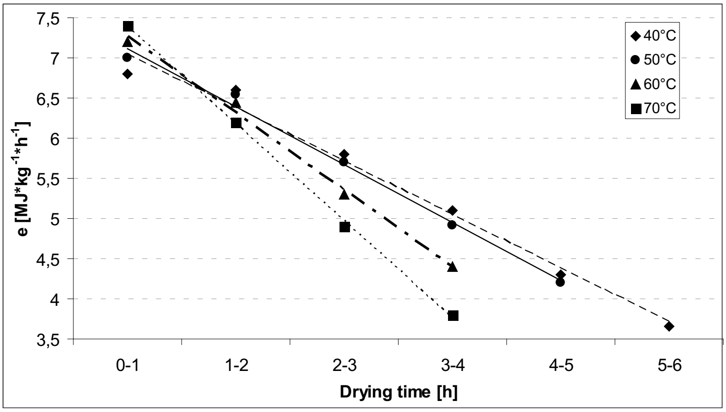

Fig. 3. Specific energy consumption during the drying of unblanched parsley (air flow velocity 0.5 ms^{-1})

Table 1. Regression equations described the relations between the specific drying energy of unblanched parsley (e) and drying time (t) – air flow velocity 0.5 ms^{-1}

t [°C]	The regression equation	R^2
40	$e = -0.6657 \cdot t + 7.7067$	0.999
50	$e = -0.724 \cdot t + 7.844$	0.994
60	$e = -0.955 \cdot t + 8.225$	0.992
70	$e = -1.21 \cdot t + 8.6$	0.984

The water blanching of parsley before convective drying caused a decrease of specific energy consumption for each level of drying temperature and for two drying air flow velocities.

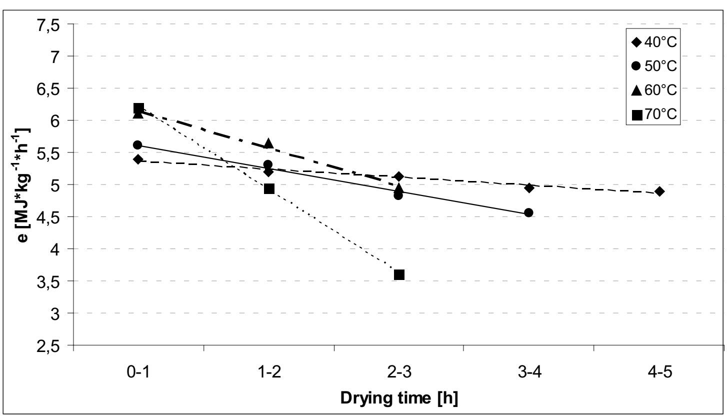

Fig. 4. Specific energy consumption during the drying of blanched parsley (air flow velocity 0.5 ms^{-1})

Table 2. Regression equations described the relations between the specific drying energy of blanched parsley (e) and drying time (t) – air flow velocity 0.5 ms^{-1}

t [°C]	The regression equation	R^2
40	e = -0,125·t + 5,491	0,963
50	e = -0,3586·t + 5,9691	0,989
60	e = -0,575·t + 6,7117	0,988
70	e = -1,3·t + 7,5165	0,999

An increase of drying air temperature from 40°C to 70°C, for two flow velocities of drying factor, caused an increase of specific energy consumption during the first hour of drying (about 0.6 $MJkg^{-1}$ and 0.8 $MJkg^{-1}$, respectively, in the case of unblanched and blanched parsley). In the subsequent time ranges, the specific energy consumption decreases, as the temperature of drying increases. It is caused by a faster decrease in water content at the higher process temperatures.

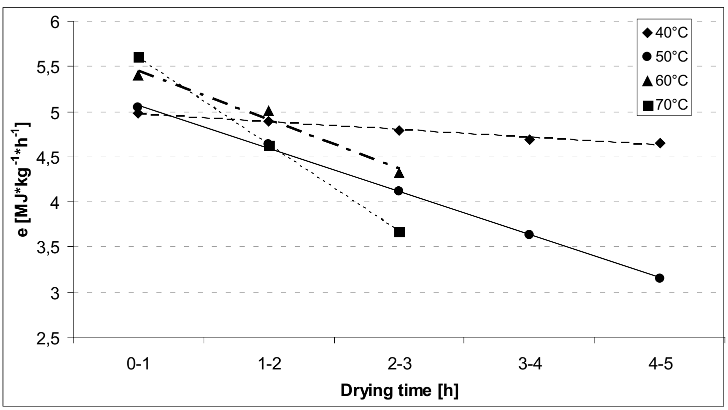

Fig. 5. Specific energy consumption during the drying of unblanched parsley (air flow velocity 1.0 ms^{-1})

Table 3. Regression equations described the relations between the specific drying energy of unblanched parsley (e) and drying time (t) – air flow velocity 1.0 ms^{-1}

t [°C]	The regression equation	R^2
40	e = -0,086·t + 5,058	0,983
50	e = -0,4801·t + 5,5569	0,998
60	e = -0,541·t + 6,7117	0,974
70	e = -0,9625·t + 6,56	0,999

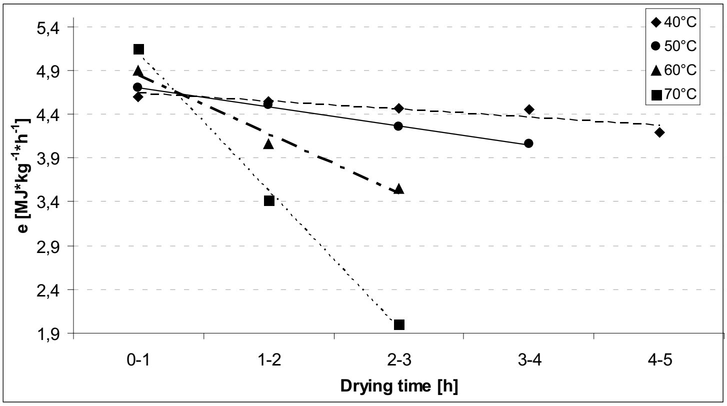

Fig. 6. Specific energy consumption during drying of blanched parsley (air flow velocity 1.0 ms^{-1})

Table 4. Regression equations described the relations between the specific drying energy of blanched parsley (e) and drying time (t) – air flow velocity 1.0 ms^{-1}

t [°C]	The regression equation	R^2
40	$e = -0,0919 \cdot t + 4,7244$	0,835
50	$e = -0,217 \cdot t + 4,92$	0,997
60	$e = -0,673 \cdot t + 5,5163$	0,979
70	$e = -1,5752 \cdot t + 6,6719$	0,996

The increase of drying air flow velocity from 0.5 ms^{-1} to 1 ms^{-1}, at the given temperature level, caused the decrease of specific energy consumption during the drying process. The increase in air flow velocity in the first hour of the process duration, from 0.5 ms^{-1} to 1 ms^{-1} resulted in the decrease of electric energy from 1.6 to 1.9 $MJkg^{-1}$ and from 0.8 to 1.2 $MJkg^{-1}$ for unblanched and blanched parsley, respectively.

The increase of drying temperature and air flow velocity as well as the use of blanching caused a decrease of total drying energy necessary to dry 1 kg of parsley (Fig. 7).

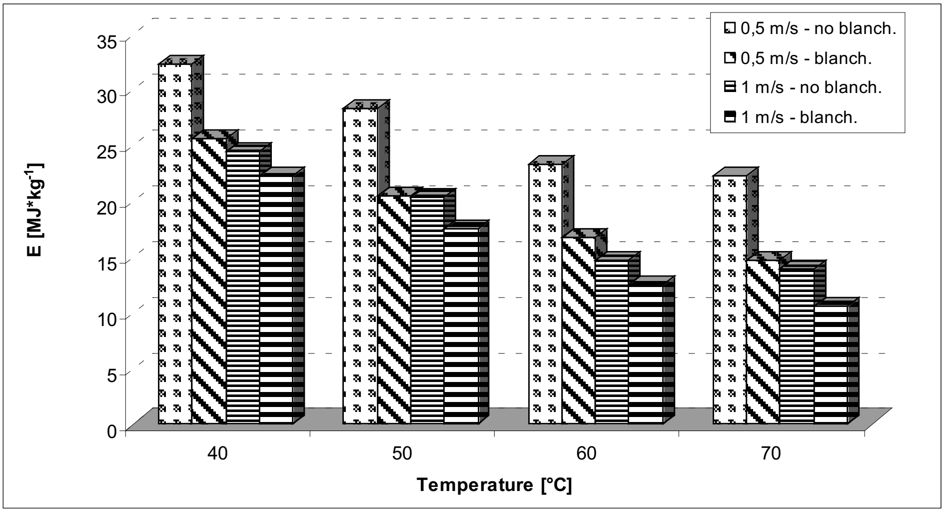

Fig. 7. Total drying energy of parsley

The highest average total drying energy (32.2 MJkg^{-1}) was obtained for unblanched parsley at 40°C and for the flow velocity of 0.5 ms^{-1}.

For each drying temperature, the total drying energy was lower in the case of the flow velocity 1.0 ms^{-1} and decreased after blanching. The lowest average total drying energy, at nearly 10.5 MJkg^{-1} , was obtained for blanched parsley dried at the temperature of 70^{o}C.

CONCLUSIONS

Based on the conducted analyses, the following conclusions can be drawn:

1. For each drying temperature blanching caused a significant decrease of parsley drying time.
2. The specific drying energy during convective drying linearly decreased as the drying time increased.
3. The increase of drying air temperature from 40°C to 70°C caused the decrease of total drying energy by nearly 43% (air flow 1 ms^{-1}), and 31% (air flow 1 ms^{-1}) for unblanched parsley, and by nearly 52%, and 42% (air flow 0.5 ms^{-1}) in the case of blanched material.
4. The lowest average total drying energy, by nearly 10.5 MJkg^{-1} , was obtained for blanched parsley dried at the temperature of 70^{o}C, and for the air flow velocity of 1.0 ms^{-1}.

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ANALIZA WPŁYWU BLANSZOWANIA I WARUNKÓW KONWEKCYJNEGO SUSZENIA PIETRUSZKI NA ENERGOCHŁONNOŚĆ PROCESU

Streszczenie. Zbadano wpływ temperatury (40, 50, 60, 70°C) i szybkości przepływu powietrza suszącego (0,5 i 1 ms^{-1}) oraz blanszowania wodnego (3 min.), na jednostkowe zużycie energii w czasie trwania suszenia konwekcyjnego oraz sumaryczną energochłonność procesu. Wzrost temperatury powietrza suszącego, w zakresie 40-70°C powoduje zmniejszenie całkowitych nakładów energetycznych o około 43% - 1 ms^{-1} i 31% - 0,5 ms^{-1} w przypadku pietruszki nie blanszowanej oraz o 52% - 1 ms^{-1} i 42% - 0,5 ms^{-1}, dla surowca blanszowanego. W całym zakresie temperatury całkowite nakłady energetyczne były niższe przy prędkości przepływu powietrza 1,0 ms^{-1} i malały w wyniku blanszowania. Najniższe średnie nakłady energetyczne wynoszące około 10,5 $MJkg^{-1}$ uzyskano w przypadku pietruszki blanszowanej i suszonej w temperaturze 70°C, przy prędkości przepływu 1 ms^{-1}.

Słowa kluczowe: suszenie konwekcyjne, energochłonność procesu, pietruszka.