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The impact of ultrasound and steam blanching pre-treatments on the drying kinetics, energy consumption and selected properties of parsley leaves

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ABSTRACT

In current study the influence of ultrasound pre-treatment and drying conditions (microwave power, air temperature) was analysed by the means of drying kinetics, energy consumption and selected quality properties of dried parsley leaves. Ultrasound treatment (US) was compared with conventional treatment – steam blanching. In comparison to untreated material, ultrasound applied at 21 kHz, 12 W/g, contributed to significant reduction of the drying time up to 29.8%. Moreover, the energy expenditures were reduced maximally by 33.6% for parsley dried at 30 °C and 300 W. For this sample the colour retention was the highest, as well. In turn, steam treated parsley was dried maximally by 28.9% faster and thus specific energy consumption decreased to 72.0% of the value for intact leaves when 20 °C and 300 W were set. The influence of pre-drying treatment on the quality properties depended on the drying conditions. Pre-drying treatment (US, blanching) did not affect the lutein content significantly, whereas the most considerable increase of chlorophyll a and b resistance and their relative concentration (Chl a/b ratio) was achieved in US-treated leaves dried at 30 °C and 100 W. The utilisation of drying pre-treatment and dehydration parameters should be considered with respect to further utilisation of dried parsley leaves. Nonetheless, sonication is worth to be taken into account due to a significant reduction of energy expenditures and an improvement of resistance of bioactive components.

1. Introduction

Nowadays, consumers are more aware of nutritional value of food and its impact on health and proper functioning of the body. Parsley leaves contain high amount of chlorophyll a and b, vitamin C, carotenoids (mainly lutein) and other antioxidants [24,28,31]. Chlorophylls and carotenoids play crucial role in photosynthesis and are responsible for colour of leaves and their perception by the consumers. Plenty of studies confirmed antimutagenic and antioxidant activity of both pigments [15,10]. In addition, lutein consumption can protect from cataract formation and macular degeneration causing vision loss [37,16]. Due to the fact that animals are unable to produce aforementioned components, their preservation during food processing is recently a concern of food manufacturers.

Drying process prolongs shelf life of food through reduction of the water activity, which ensures product's stability. However, it is well known that vitamins, colourants and antioxidants are sensitive to high air temperature values, which imposes use of lower dehydration temperature and considerably decrease drying intensity [18]. On the other hand, even when drying is carried out at low temperature, a prolonged exposition to the oxygen could decrease nutrient content significantly [17,31].

Different drying methods and pre-treatments were examined in order to decrease the air temperature and reduce the drying time. Among them, microwave-supported convective drying exhibited colour and active components protection, compared with other drying methods [2,28]. Various treatments preceding drying were applied successfully, as well. The most basic is steam blanching carried out in the steam chambers. This treatment leads to deactivation of the enzymes, removes oxygen from intercellular spaces and thereupon may protect the colour and nutritional value of the food [6].

Novel ways of conducting the drying process focus more on the non-thermal technologies like sonication. Application of ultrasonic waves is associated with a cavitation phenomenon as well as alternative cycles of compressions and rarefactions of the material ('sponge effect') [38]. Ultrasound generated in a liquid medium induces growing and collapsing of gas bubbles. Those, that are in

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close proximity of the solid, collapse asymmetrically, releasing fountain of the microbubbles, damaging the structure and thereby creating microscopic channels [14,20,38]. As a consequence, a higher mobility of internal water is observed, which accelerates the water evaporation during drying [38,26]. Thanks to that, ultrasound has been successfully applied prior to drying of apples, bananas and parsley leaves [20,26,3,30]. Moreover, a higher retention of biological components in sonicated samples was noticed in fruits and herbs [9,29,31] but its value depended on drying and treatment parameters.

Therefore, it was necessary to adjust the processing conditions for parsley leaves. The objective of this study was to investigate the impact of ultrasound and steam blanching on the microwave-convective drying kinetics, energy consumption and selected quality properties of parsley leaves. The influence of microwave power set (100 and 300 W) was also studied for varied air temperature (20, 30 and 40 °C) and type of treatment.

2. Materials and methods

2.1. Material

Parsley leaves (*Petroselinum crispum*) were selected to the experiment as a popular seasoning herb in Poland and other countries. Pots of plants were bought from hydroponic cultivation of "Swedeponic" greenhouse (Krasnicza Wola, Poland). Plants were kept under the exposure to the sunlight at temperature of 20 ± 1 °C for no longer than 2 days, during which they were watered regularly. Mature and healthy leaves were collected directly before the pre-treatments (ultrasound, steam blanching and dipping in water). Dry matter content was determined accordingly to Shreve et al. [27].

2.2. Pre-treatments

2.2.1. Ultrasound pre-treatment (US)

The ultrasound pre-treatment was carried out for 20 min in an ultrasound bath at frequency of 21 kHz. The total power generated by sonotrodes was 300 W, which corresponded to the ultrasound intensity of 12 W per gram of material (0.29 W/g when considering the total mass of the material and the medium). The parameters of sonication were chosen based on the previous study due to the best quality of dried leaves (polyphenols content, colour) and high reduction of the drying time [29]. Leaves of a weight of 25 g were directly dipped in 1 L of distilled water (22.3 ± 0.7 °C) and covered by a metal net in order to provide the full immersion in the liquid medium. The ratio of the material to the water was 1:40 (w/w). During the sonication the water temperature increased maximally by 0.8 ± 0.2 °C. After the pre-treatment leaves were placed on filter paper to remove excess water from the surface to the final mass of 30 g. Directly afterwards material was dried in microwave-convective oven.

2.2.2. Steam blanching (STEAM)

Parsley leaves were subjected to the steam blanching over the boiling water (99 ± 1 °C). For that purpose, the material was placed on the sieve in a single layer. This procedure was repeated four times and the total mass of the leaves treated by steam amounted to 25 g. Every time the release of the water steam affected the parsley surface for 3 s, after which a turgor of the leaves was still remained. The lack of significant mass changes affected by blanching treatment was noted. Leaves were subsequently transferred into a vessel, where material was cooled in distilled water at ambient temperature (21 ± 1 °C) for 20 min, which corresponded to the time of soaking during ultrasound pre-treatment. The material to water mass ratio was similar to the US-treatment (1:40 w/w). Then, the excess water was removed from the surface, as it was described above.

2.2.3. Dipping – untreated material (UNTR)

In order to eliminate the effect of soaking during ultrasound and water steam blanching pre-treatments, a part of freshly collected leaves was placed in distilled water (21 ± 1 °C, 20 min). The material-water ratio and the procedure of leaves surface's dewatering were similar like in the case of ultrasound and blanching treatments.

2.3. Microwave-convective drying

Directly after removing excess water from the materials' surface, the ultrasound treated, blanched and dipped leaves were dried in a laboratory microwave-convective dryer (Promise Tech Inc., Wroclaw, Poland) at varied microwave power (100 and 300 W) and air temperature (20, 30 and 40 °C). A constant velocity was set at 0.7 m s^{-1}. The leaves were placed on a rotating, cylindrical sieve, with load of 0.7 kg m^{-2}. The air was flowing transversely to the layer of the material. The drying was performed until water content below 0.1 kg kg d.m.$^{-1}$ was achieved (the weight of dried leaves was around 2.1 ± 0.1). Mass of the material was recorded continuously during drying with the accuracy of ±0.1 g. The experiments were repeated two times.

2.4. Drying kinetics

The drying curves were plotted as a function of a dimensionless moisture ratio (*MR*) during time of drying, according to formula presented by Midilli et al. [19]:

$$MR = u_\tau / u_0$$

where u_0 – initial moisture content (kg H_2O kg d.m.$^{-1}$) and u_τ – moisture content at each moment of the process (kg H_2O·kg d.m.$^{-1}$)

In order to describe the drying kinetics the logistic model [34] and the model previously presented by the authors [30] were used, whose equations are as follows:

Logistic model [34]:

$$MR = b/(1 + a \cdot \exp(k \cdot \tau))$$

Sledz et al. [30] model:

$$MR = b \cdot \exp(-k \cdot \tau)/(1 + a \cdot \exp(k_i \cdot \tau))$$

where k, k_i – drying coefficients (min^{-1}); a, b – coefficients of the equations; τ – time (min).

2.5. Energy consumption

Drying energy consumption and energy consumed during US-treatment were measured in kWh by Pawbol meter (Sułkowice, Poland) and Voltcraft Energy Logger 4000F (Hirschau, Germany), respectively. The specific energy consumption was expressed as an energy consumption during drying per kg of evaporated water.

2.6. Chlorophylls and lutein contents

Chlorophyll a and b and lutein contents were determined with Waters ACQUITY Ultraperformance Liquid Chromatography (UPLC) coupled with a Photodiode Array detector (PDA), according to the method proposed by Guzman et al. [11]. Pigments were extracted from 0.05 g of dried leaves by 25 cm^3 of 80% acetone at 10 °C. Approximately 0.1 g of $MgCO_3$ was added to all samples in order