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Selected chemical composition changes in microwave-convective dried parsley leaves affected by ultrasound and steaming pre-treatments – An optimization approach

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ABSTRACT

Parsley leaves contain a high amount of bioactive components (especially lutein), therefore it is crucial to select the most appropriate pre-treatment and drying conditions, in order to obtain high quality of dried leaves, which was the aim of this study. The optimization was done using response surface methodology (RSM) for the following factors: microwave power (100, 200, 300 W), air temperature (20, 30, 40 °C) and pre-treatment variant (ultrasound, steaming and dipping as a control). Total phenolic content (TPC), antioxidant activity, chlorophyll and lutein contents (using UPLC-PDA) were determined in dried leaves. The analysed responses were dependent on the applied drying parameters and the pre-treatment type. The possibility of ultrasound and steam treatment application was proven and the optimal processing conditions were selected.

1. Introduction

Parsley (*Petroselinum crispum*) is a biennial plant, usually grown as an annual plant (Peter, 2012). Parsley originated from Sardinia, but nowadays is cultivated in almost the whole of Europe, in the USA and in North Africa (mainly in Algeria) (Charles, 2012). Parsley is characterized by a specific fresh aroma. Hence, it is used for food seasoning. Due to its high content of different bioactive components, it is used also in medicines and dietary supplements, as well as in cosmetics (Charles, 2012).

Parsley leaves contain a number of different antioxidants – among which flavones (apigenin and luteolin), xanthophylls (lutein and zeaxanthin), as well as some components of its essential oil, such as apiol and myristicin, can be distinguished (Pokorný & Pánek, 2012). Parsley is one of the major sources of lutein (which exhibits both antioxidant activity and prevents cataract or age-related macular degeneration) in the human diet (Perry, Rasmussen, & Johnson, 2009; Žnidarčič, Ban, & Šircelj, 2011). Lutein plays also a protective role in the photosynthetic system, due to its scavenging activity against reactive oxygen species (ROS) (Fu, Magnúsdóttir, Brynjólfson, Palsson, & Paglia, 2012; Lefsrud, Kopsell, Wenzel, & Sheehan, 2007). Brobst (2012) states that high chlorophyll content in parsley leaves provides them with antiseptic properties. Moreover, parsley leaves contain high amounts of vitamins A, B_1, B_2 and C, as well as iron, calcium, magnesium and potassium (Brobst, 2012; Charles, 2012; Peter, 2012). The presence of these bioactive compounds makes parsley useful in medical application, for instance in nephrolithiasis, gout prevention or in liver detoxification (Charles, 2012; Kurian, 2012; Peter, 2012). Parsley extracts exhibit free radical scavenging activity (Charles, 2012; Pokorný & Pánek, 2012).

Microwaves have been used for several years to enhance drying. The mechanism of their effect on the evaporation process is linked to oscillation of water (as a dipole) and acceleration of ions in a changing electromagnetic field. These phenomena cause friction that generates heat (Regier & Schubert, 2001). Many studies have confirmed a higher quality of microwave dried products, compared to conventional drying, especially when herbal materials were dried (Arslan, Özcan, & Mengeş, 2010; Brewer, 2005; Nowacka, Sledz, Wiktor, & Witrowa-Rajchert, 2012).

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In recent years, interest in ultrasound has increased, as this technique is considered to be a non-thermal pre-treatment prior to drying of products abundant in thermo-sensitive compounds. Ultrasound is an energy which is transmitted in the form of changing pressure wave, that causes air vibration over a frequency range from 18 kHz to 100 MHz (Kentish & Ashokkumar, 2011; Nowacka, Wiktor, Sledz, Jurek, & Witrowa-Rajchert, 2012; Witrowa-Rajchert, Wiktor, Sledz, & Nowacka, 2014). Propagation of ultrasound depends on constantly changing cycles of low and high pressure, liquid stirring and the phenomenon of extremely quick release of high doses of energy, which can impact upon the chemical properties of tissue (Kentish & Ashokkumar, 2011; Witrowa-Rajchert et al., 2014). The use of ultrasound prior to drying still remains on a laboratory scale, due to lack of knowledge in the field of its impact on drying course and the quality of final product. Preliminary research in this domain is very promising and creates the opportunity for possible industrial application of ultrasound to enhance drying processes (Leadley & Williams, 2006).

The objective of the current study was to optimize the microwave-convective drying conditions and pre-treatment method of parsley leaves related to the total phenolic content (TPC), antioxidant capacity, chlorophyll and lutein contents.

2. Materials and methods

2.1. Material

The leaves of parsley (*Petroselinum crispum*) were collected from pots that were bought from hydroponic cultivation of "Swedeponic" greenhouse (Krasnicza Wola, Poland). Plants were kept exposed to sunlight for a maximum of 2 days (20 ± 1 °C). Mature and healthy leaves were collected directly before the pre-treatments (ultrasound, steaming and dipping in water).

2.2. Design of experiment

The experiment concerning the influence of the type of pre-treatment (ultrasound, steaming, dipping) and drying parameters (microwave power and air temperature) on selected properties of dried parsley leaves was designed and analysed with Design-Expert software v. 10 (Stat-Ease Inc., Minneapolis, MN). For this purpose, a three-level factorial design based on response surface methodology (RSM) was used with two quantitative (microwave power, air temperature) and one qualitative (type of treatment) factor. The A – air temperature and B – microwave power factors were standardized, however, due to the fact that the factor C (type of treatment) was the qualitative factor; normalization was impossible to carry out by the software. The plan assumed 39 experiments with combination of each factor at each level with five repetitions at the "central point" (200 W, 30 °C) for each treatment. Actual and normalized values of 39 experimental runs are summarized in Table 1.

2.3. Pre-treatments

2.3.1. Ultrasound pre-treatment (US)

The ultrasound pre-treatment was performed by immersive method in an ultrasonic bath (model No. MKD-3; MKD Ultrasonic, Konik Stary, Poland). The following processing conditions were used: a frequency of 21 kHz, time of treatment 20 min and total power output of 300 W, which corresponded to 12 W/g of ultrasound intensity. The parameters of sonication were chosen based on a previous study, based on the availability of the most biologically active components (Sledz, Nowak, & Witrowa-Rajchert, 2014; Sledz, Wiktor, Nowacka, & Witrowa-Rajchert, 2017). Leaves of a weight equal to 25 g were collected directly before the treatment, dipped in tap water (1 L, 22.3 ± 1.6 °C) and covered by metal mesh to provide full immersion in the liquid medium. The ratio of material to the water equaled 1:40 (*w/w*). After the pre-treatment, the leaves were placed on a filter paper to remove excess water from the surface. Directly afterwards, the material was dried in a microwave-convective oven.

2.3.2. Steaming pre-treatment (STEAM)

The leaves of parsley were subjected to steaming over boiling water. For that purpose, the material was placed in a sieve in a single layer and the steam affected the parsley's surface for 3 s. The leaves were subsequently transferred into a vessel, where the material was cooled in tap water at ambient temperature (21 ± 1 °C) for 20 min, which corresponded to the time of soaking during ultrasound pre-treatment. The mass of the leaves, as well as the material to water ratio was similar as in the case of the US treatment (1:40 *w/w*). Then, the excess water was removed from the surface, as described above.

2.3.3. Dipping (CONTROL)

Dipping was selected for a control treatment, in order to eliminate the effect of soaking during ultrasound and steaming pre-treatments. The material was placed in tap water (21 ± 1 °C) for 20 min. The initial mass of parsley leaves, the material-to-water ratio and the procedure of dewatering of leaf surfaces were similar to the ultrasound and steam treatments.

2.4. Microwave-convective drying

Parsley leaves treated by ultrasound, steam and after dipping were dried in the microwave-convective oven (Promis-Tech Inc., Wroclaw, Poland) under varied microwave power (100, 200 and 300 W) and air temperature (20, 30 and 40 °C). The microwave frequency was 2450 MHz. The air velocity during the process was constant (0.7 m/s). The leaves of a mass of 24 g were placed on a rotating, cylindrical sieve positioned perpendicular to air flow, with load: 0.7 kg/m^2. Drying was performed until water content reached below 0.1 kg/kg of dry matter (d.m.)

2.5. Total phenolic content (TPC)

Extraction of polyphenolic compounds from fresh and dried parsley leaves was carried out using 80% ethanol solution in three repetitions for each material. The extracts were subsequently used for both TPC and antioxidant capacity determinations. In brief, 30 mL of 80% ethanol were added to 2 g of fresh leaves (approx. 0.2 g of dried material), homogenized (1 min, 30 000 rpm; IKA T10, IKA Werke GmbH, Staufen, Germany), boiled (2 min), filtered and 80% ethanol was added to achieve 50 mL. Detailed description of extraction procedure was presented by Sledz, Nowacka, Wiktor, and Witrowa-Rajchert (2013), and Nowacka, Sledz, Wiktor, and Witrowa-Rajchert (2014). The extracts were stored at −18 °C for no longer than 24 h. Before determination the extracts were warmed to room temperature (approx. 20 °C), filtered and used for further determinations.

In order to determine TPC the Folin-Ciocalteu method was used according to Singleton and Rossi (1965) with the following modifications. Water (8.2 mL), extract (0.3 mL) and Folin-Ciocalteu's reagent (0.5 mL) were transferred into tubes, mixed and after 3 min 1 mL of 1.7 M sodium carbonate was added. The solution was again stirred and afterwards stored in the dark at room temperature for 1 h. At the same time, in an analogous way the blank sample was prepared, where the volume of the extract was replaced by 0.3 mL of distilled water. After 1 h, the absorbance at 750 nm against the blank sample was measured (Helios γ