DRYING OF PARSLEY LEAVES PRE-TREATED BY ULTRASOUND*

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Summary. The purpose of the study was to evaluate the effect of ultrasound pre-treatment (US) on the kinetics of microwave-convective drying and selected quality parameters of parsley leaves. The sonication was performed at different frequencies (21 and 35 kHz) for various time (20 or 30 min). Treated leaves were subjected to the microwave-convective drying (200 W, 30°C). In dried parsley the total phenolic content (TPC) and colour changes were determined and compared with untreated dried leaves. The results indicated that with respect to untreated leaves, an ultrasound pre-treatment resulted in shortening of the drying time by 11–56%, unchanged or slightly decrease of total phenolic content (TPC) and mostly better colour protection. Application of ultrasound at 21 kHz was recommended for parsley leaves due to giving the highest phenolic concentration and the most fresh-like colour what was probably associated with high reduction of drying duration (47–52%).

Key words: parsley, leaves, ultrasound, microwave drying, polyphenols, colour

INTRODUCTION

Parsley is a green leafy vegetable, widely cultivated in Poland mainly as a biennial plant. The leaves of parsley contain considerable amount of ascorbic acid, iron and vitamin A [Charles 2004]. Due to high content of essential oils parsley is widely used for seasoning dishes. Nonetheless, the presence of volatile compounds forces utilisation of lower temperature during convective drying which consequently decrease the intensity of the process significantly [Matrynenko and Kudra 2014]. Moreover, as Doymaz et al. [2006] presented, both longer drying time (lower air temperature) and higher temperature...
used during convective drying of parsley leaves resulted in worse quality of the product. It was previously proved that application of microwaves during convective drying results in process intensification and thus reduction of energy expenditures and simultaneously increase the quality of herbs [Alibas 2010, 2014, Nowacka et al. 2012, Sledz et al. 2013, Wiktor et al. 2013], and also during their further storage [Sledz and Witrowa-Rajchert 2012a]. For instance, a 45% higher phenolic content (compared with fresh mint leaves) was notified after microwave drying, probably due to the liberation of the components during this process [Arslan et al. 2010]. For that reason, nowadays this method is more frequently suggested for herbal drying and the number of industrial microwave dryers proposed for aromatic plants drying continually grows.

Recently, scientists are focused on the utilisation of non-thermal technologies in order to intensify the drying process. This is particularly relevant in drying of materials contain considerable amounts of bioactive components because of its heat sensitivity. In this context, the ultrasound (US), technique based on the propagation of an acoustic wave of frequency above 16 kHz, is a promising technology due to cheapness of device and low operation costs [Soria and Villamiel 2010, Witrowa-Rajchert et al. 2014]. The sonication, discovered by Pierre Curie in 1880 and initially utilised mainly in cleaning [Mason 2003] nowadays experiences a renaissance. From the food engineering point of view, the high-intensity range of ultrasound (frequency 20–100 kHz, intensity above 1 W·cm⁻²) is especially interesting, since it causes a modification of a tissue microstructure and thereby increases the heat and mass transfer [Chemat et al. 2011, Nowacka et al. 2012, Witrowa-Rajchert et al. 2014]. It should be highlighted that the impact of sonication is dependent not only on the type of medium used in the treatment (liquid, gas or supercritical stage) but on the processing conditions (temperature, ultrasound intensity, frequency, amplitude, material to medium ratio, time of treatment), as well [Cárcel et al. 2012]. The microstructure, especially porosity determines the susceptibility of the material to the sonication [Ozuna et al. 2014] and therefore sonication parameters should be adjusted for each material separately.

The objective of current study was to assess the effect of ultrasound pre-treatment applied at different frequencies (21 and 35 kHz) for various time (20 or 30 min) on the kinetics of microwave-convective drying and selected quality parameters of parsley leaves.

**MATERIAL AND METHODS**

The experimental material consisted leaves of parsley (*Petroselinum crispum* L.). Pots of plants were bought from hydroponic cultivation of “Swedeponic” greenhouse (Kraśnicza Wola, Poland). Plants were kept at temperature of 20 ±1°C for no longer than 2 days. Mature and healthy leaves were collected directly before the ultrasound pre-treatment (US).

Sonication was performed in ultrasound baths giving frequencies of 21 kHz (MKD-3, Ultrasonics) or 35 kHz (IS-3, InterSonic) for 20 or 30 min. The internal dimensions of both baths were the same. Treatment was carried out at an ambient temperature (20 ±2°C) at leaves to tap water ratio totalled 1 : 50. After the pre-treatment the excess water from the material surface was removed using a filter paper to obtain
a constant mass. To eliminate the influence of soaking during US treatment, untreated material was immersed in water for 20 min.

Ultrasound pre-treated leaves were subsequently dried using microwave-convective laboratory dryer at constant microwave power (200 W), air temperature (30°C) and its velocity (0.8 m·s⁻¹). The dryer was loaded with 0.7 kg·m⁻². The process was stopped after achieving constant weight, corresponding to moisture content around 0.07 kg of H₂O·per 1 kg of dry matter.

The mass changes were recorded using digital balance in two-minute intervals. Dried material were packed in foil packaging (BOPA/PE 1540FF), removing 70% of the air from the bag. Drying curves were presented as the changes of moisture ratio (MR) in time of drying, where MR was computed as a water content at particular time of process (uₜ) vs. water content at the initial stage of the drying (u₀): MR = uₜ/u₀.

The total phenolic content (TPC) was determined using Folin-Ciocalteu method, as it was described formerly [Sledz et al. 2013]. The extracts were prepared with 80% ethanol in two repetitions for each material, whilst the TPC was measured in duplicated for each extract. The calibration curve was performed for gallic acid standard.

The colour of dried leaves was recorded using a reflective mode and CIE L*a*b* system (Konica-Minolta, CR-5). The measurement conditions were: D65 standard illuminate, 2° Standard Observer, measurement diameter: 30 mm. The whole, not fragmented leaves were placed inside the Petri dish in a two-centimeters layer. The colour analysis was carried out in six repetitions, each time the leaves were arranged in a different way. The chroma (C) was calculated as follows: C = \sqrt{(a*)² + (b*)²}.

In order to determine the quality changes in leaves affected by the different parameters of the ultrasound treatment the ANOVA coupled with Tukey HSD test were used at α = 0.05 (STATISTICA 10 software).

RESULTS AND DISCUSSION

The kinetics of the microwave-convective drying of parsley leaves are presented in Figure 1. The process lasted the longest in the case of untreated material and to achieve the MR = 0.02 it has totalled 32 min (Table 1). Ultrasound pre-treatment induced the intensification of water evaporation, especially when the sonication lasted 20 min, irrespectively of the applied ultrasonic (US) frequency. The above mentioned moisture ratio was reached after 15.5 min for US-treated sample at 21 kHz for 20 min and 17 min for parsley sonicated at the same frequency for 30 min, which means that the drying time was reduced by 52 and 47%, respectively. In turns, application of sound waves at 35 kHz resulted in drying time savings varied from 11 to 56%, depending of the time of the treatment. A considerable enhancement of the leafy materials drying was observed also in other studies. The process was shortened by 30% when the sonication parameters of parsley leaves was set at 21 kHz, 20 min at the equivalent drying conditions [Sledz et al. 2014b]. Similar results were obtained for US-assisted convective drying of olive leaves, for which the drying time was reduced up to 50% at the highest ultrasound density [Cárcelet al. 2010].

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It can be concluded that irrespectively of US frequency sonication carried out over 20 min resulted in a significantly higher intensification of the dehydration process of parsley leaves. Similar findings were described also by Nowacka et al. [2012]. In their study, longer time of US application contributed to lower shortening of the drying time. Moreover, application of 21 kHz led to considerable higher reduction of drying duration. It appears that there exist optimal conditions of ultrasound treatment that accelerate the heat and mass transfer processes.

Available scientific literature does not give a definite answer regarding an impact of ultrasonication on the content of phenolic compounds. It is known that degradation of bioactive components may occurs in the presence of ultrasound application [Kentish and Ashokkumar 2011, Santacatalina et al. 2014]. On the other hand, with respect to the untreated sample ultrasound contributes to a higher value of concentration of determined chemical component due to its better extraction [Sledz et al. 2014a, Tao et al. 2014, Witrowa-Rajchert et al. 2014]. In present study, the TPC in untreated dried leaves was the highest and totalled 23.88 ±0.54 mg per 1 g of dry matter. Similar results were presented previously for microwave-convective dried parsley leaves [Sledz et al. 2013]. Ultrasound predominantly contributed to significant degradation of the total phenolic content (TPC).
Drying of parsley leaves pre-treated by ultrasound

in microwave-convective dried parsley leaves (Fig. 2). The only exception was parsley subjected to ultrasound for 30 min at 21 kHz, for which an irrelevant loss (5%) of polyphenols was noted, with respect to intact dried parsley leaves. The highest degradation (equalled 20.8%) occurred when sonication parameters 35 kHz, 20 min were set. As Santacatalina et al. [2014] suggested, a mechanical stress accompanying ultrasound application can result in phenolic degradation due to release of oxidative enzymes and intra-cellular compounds into the solvent. It should be highlighted that the highest TPC degradation occurred when the highest intensification of the drying process was noted. Perhaps a very intensive evaporation may enhance a decomposition of active components, as it was observed formerly [Sledz et al. 2014a].

The colour of green leafy vegetable is a basic indicator of chlorophyll and carotenoids changes. Taking into account the CIE L*a*b* system, the coefficient a* is the most sensitivity in this context. In turn, chroma is a parameter describing saturation of colour and its intensity, highly important for colourants-rich materials. It is important to obtain a product that has virtually unchanged colour with respect to fresh leaves. The a* and chroma values of fresh parsley leaves amounted to $-13.67 \pm 0.41$ and $25.79 \pm 0.91$, respectively. Variation of these coefficients in dried parsley is shown in Figures 3 and 4. The ultrasound treatment influenced the green colour (negative values of a* parameter) and colour saturation significantly. Parsley subjected to the US-treatment (21 kHz 20 min, 21 kHz 30 min and 35 kHz 20 min) was characterized by mostly more intensive green colour (up to 8% lower a* values, in comparison to intact leaves) that was associated with considerable higher saturation (Fig. 4). These sonication conditions caused also the highest reduction of the drying time (Table 1). It can be therefore stated that shortening of the exposure to
the high temperature and microwave energy doses during drying contributed to protection of colour and probably higher retention of the chlorophylls, as well. It was formerly confirmed that lower a* and higher chroma values were strongly correlated with higher chlorophylls content in parsley leaves [Sledz and Witrowa-Rajchert 2012a].

On the contrary, decrease in the total colour change coefficient (ΔE) affected by sonication was observed by Kek et al. [2013] for guava slices. The authors suggested that it resulted from more intensive enzymatic browning, as a consequence of release of tissue juice from collapsed cells. In present study, the a* parameter changes to less green-like
colour and lower chroma values were noticed only in the case of sample named as US 35 kHz 30 min. However, in this case it can be explained by an impair of chlorophylls’ structure, manifested by worse colour of sample with longer sonication time at 35 kHz and longer drying time (Table 1).

Dried parsley leaves demonstrated the most fresh-like colour after ultrasound treatment at 21 kHz, irrespectively of the time of sonication. Therefore this frequency should be recommended for parsley drying in order to preserve the colour of leaves.

CONCLUSIONS

1. Ultrasound application contributed to shortening of the drying time from 11 to 56%, depending of the sonication conditions.

2. Leaves subjected to ultrasound treatment were characterised by mainly lower phenolic content but better colour, compared with untreated material. Only in the case of treatment at 21 kHz for 20 min the TPC was unchanged, whereas the colour was the most similar to the fresh leaves when the frequency of 21 kHz during pre-treatment was set. It can be stated that despite of degradation of phenolic compounds caused by ultrasound, the most noticeable shortening of the drying time after sonication contributed to better preservation of phenolic content, and probably also chlorophylls that guarantee the green colour of parsley leaves.

3. The ultrasonication at 21 kHz may be recommended for parsley leaves drying due to considerable reduction of drying time (47–52%) and the best phenolic content and colour preservation, however, the quality was dependent on the US treatment parameters. Higher intensification was observed when this frequency was applied for 20 min, however, the quality of leaves was slightly better after 30 min of treatment.

REFERENCES


Streszczenie. Celem pracy była ocena wpływu obróbki wstępnej za pomocą ultradźwięków na kinetykę suszenia mikrofalowo-konwekcyjnego oraz wybrane właściwości liści pietruszki. Sonikacja była przeprowadzona przy różnych częstotliwościach (21 and 35 kHz) przez zmienny czas (20 lub 30 min). Liście po obróbce poddawano suszeniu mikrofalowo-konwekcyjnemu (200 W, 30°C). W suszonej pietruszce oznaczano zawartość polifenoli ogółem (TPC) oraz zmiany barwy, które porównano z odpowiednimi wskaźnikami suszonych liści niepoddanych obróbce wstępnej. Wyniki wskazują, że w stosunku do liści niepoddanych obróbce wstępnej, ultradźwięki spowodowały skrócenie czasu suszenia o 11–56%, nie zmieniły lub spowodowały nieznaczne obniżenie zawartości polifenoli ogółem (TPC) oraz wpłynęły na lepsze zachowanie barwy. Aplikacja ultradźwięków o częstotliwości 21 kHz została zarekomendowana w przypadku liści pietruszki, gdyż skutkowała największą zawartością polifenoli oraz barwą najmniej zmienioną w stosunku do świeżych liści, co prawdopodobnie było związane ze znacznym skróceniem czasu suszenia (47–52%).

Słowa kluczowe: pietruszka, liście, ultradźwięki, suszenie mikrofalowe, polifenole, barwa