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The effect of blanching temperature on the quality of microwave-vacuum dried mushroom *Cantharellus cibarius*

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Abstract. The objective of this study was to evaluate the effect of blanching temperature on structure, colour, chemical composition, and rehydration capacity of microwave-vacuum dried chanterelle (*Cantharellus cibarius*). Fruiting bodies of chanterelle were collected from the forests in Jelgava region of Latvia. Prior to drying, fresh mushrooms were blanched in water at various temperatures of 70, 80, 90 and 100ºC for 3 min, then cooled in water (20ºC). After blanching mushrooms were dried in a microwave-vacuum drier according to the specially designed program. The content of dry matter of chanterelle was 9.5 ± 0.5%. The results revealed that weight loss at 70–90ºC was significantly smaller compared to blanching at 100ºC temperature. The results indicated the tendency of smaller changes in microstructure, weight loss and colour for samples blanched at 70–80°C temperature comparing to the samples unblanched or blanched at higher temperatures. Electrical conductivity in water extract of microwave-vacuum dried chanterelle decreased with increased blanching temperature. Titratable acidity of chanterelle significantly reduced after blanching due to leakage of soluble acids into blanching water.

Key words: protein content, total phenols, structure, aroma profile, rehydration capacity.

INTRODUCTION

Wild mushrooms have long been appreciated for their content of proteins and fiber (Kalač, 2009; Pereira et al., 2012), aroma and flavour (Tsai et al., 2009; Dermiki et al., 2013), minerals, vitamins and other biologically active substances (Mattila et al., 2000; Chye et al., 2008), as well as their therapeutic potential (Hong et al., 2012).

Kumari et al. (2011) in their study concluded that the chemical composition and energy values of the wild edible mushrooms of *Cantharellus* species clearly indicate that they provide key nutrients such as protein and carbohydrates. These varieties of mushrooms can also be used in low-caloric diets for their low contents of fat and energy. Besides, they are also good sources of useful amino acids and contain bioactive compounds. *Cantharellus cibarius* contains crude protein 53.7%, carbohydrates 31.9% and lipids 2.9% of the dry matter (Barros et al., 2008). Dry matter of mushrooms usually is in the range of 60–140 g kg^{-1} (Kalač, 2009). Relatively low content of dry matter and lipids result in the low energy value of mushrooms, that for *Cantharellus cibarius* is 118 kJ 100 g^{-1} of fresh mushrooms (Barros et al., 2008). Mushrooms are also characterized

by a high level of well assimilable mineral constituents. Potassium, magnesium and phosphorus containing compounds are the most abundant in *Cantharellus cibarius* (Falandysz et al., 2012). However, edible mushrooms are characterized by a short shelf life due to post-harvest changes resulting from the activity of enzymes such as polyphenol oxidase (PPO) that is responsible for browning reactions during storage (Keyhani & Keyhani, 2011).

Dehydration is among the most popular methods for shelf-life extension of highly perishable foods. Convective drying is widely used; however, several disadvantages of this method have been reported: degradation of important nutritional substances due to relatively long drying times and high temperatures (Marfil et al., 2008; Vega-Gálvez et al., 2012), changes in product colour and texture (Kotwaliwale et al., 2007), decrease in rehydration ability due to shrinkage (Giri & Prasad, 2007). Microwave-vacuum drying have been successfully applied to overcome the mentioned limitations in drying of apple slices (Schulze et al., 2014), green peas (Zielinska et al., 2013), rosemary (Calín-Sánchez et al., 2011), potatoes (Wang et al., 2010), button mushrooms (Giri & Prasad, 2007).

During microwave-vacuum drying the energy of microwaves is absorbed by water located in the whole volume of the material being dried. This creates a large vapour pressure in the centre of the material, allowing rapid transfer of moisture to the surrounding vacuum and preventing structural collapse (Lin et al., 1998; Figiel, 2010). As a consequence, the rate of drying is considerably higher than in traditional methods of dehydration (Sharma & Prasad, 2004). Giri and Prasad (2007) reported a reduction of 70–90% in the drying time of mushrooms, when hot air drying was replaced with microwave vacuum drying. Decreasing the pressure during microwave heating reduced the boiling point of water and thereby the drying temperature. (Sham et al., 2001) observed that the puffing phenomenon, that accompanies the rapid process of dehydration, creates a porous texture of the food, thus facilitating rehydration.

Pre-treatment is common in most processing operations to improve final product quality or to accelerate its drying kinetics (Lewicki, 1998). Among pre-treatments, blanching is one of the most extensive with the aim of denaturing or inactivating enzymes that adversely affect product quality (Sanjuan et al., 2000). The effective moisture diffusivity of broccoli increased from 1.987 to 3.577×10^{-8} m^2 s^{-1} as blanching temperature increased from 20°C to 80°C. Increase in blanching temperature and rehydration temperature can increase the rehydration ratio of dried broccoli pieces (Doymaz, 2014). However, since blanching is a heat treatment, changes associated with thermal processing can be expected. These include degrading and leaching of nutritive components, for example, sugars, minerals and vitamins, colour change, loss of turgor in cells, due to thermal destruction of membrane integrity and partial degradation of cell wall polymers (Bahçeci et al., 2005). Significant reductions in the texture, colour, polyphenols and antioxidant capacity were observed due to blanching of York cabbage (Jaiswal et al., 2012).

The objective of this study was to evaluate the effect of blanching temperature on structure, colour, chemical composition, and rehydration capacity of microwave-vacuum dried mushroom *Cantharellus cibarius*.

MATERIALS AND METHODS

Raw materials

Fruiting bodies of chanterelle (*Cantharellus cibarius*) were collected from the forests in Jelgava region of Latvia. Fresh mushrooms were cleaned from forest debris, washed thoroughly in running tap water, drained on perforated containers, caps exceeding 40 mm in diameter were cut into halves. Samples were processed within the first 24 h after collection.

Pre-treatment and drying

Prior to drying, fresh mushrooms were blanched in water at various temperatures of 70, 80, 90 and 100°C for 3 min, and then cooled with water (20ºC). Blanching was done immersing 0.5 kg of chanterelle in 5 l of water at appropriate temperature and then draining the excess water over a strainer. After blanching, mushrooms were dried in a microwave-vacuum drier 'Musson-1' (OOO 'Ingredient', St. Petersburg, Russia). Characteristic parameters of the drying program are presented in Table 1. All treatments were carried out in triplicate; obtained samples were combined for the further analyses.

Table 1. Characterization of microwave vacuum drying program for chanterelle

Parameters	Values
Number of magnetrons	4–3–2*
Pressure, kPa	7.47–9.33
Drum rotation speed, rpm	6
Drying time, min	12–18
Product mass, kg	0.7–1.0**

* drier was programmed gradually decreasing number of used magnetrons
** initial mass of sample to be dried depends on the amount of water lost during blanching

The following abbreviations for the samples in this work are used, according to the method of pre-treatment applied:

UB – unblanched chanterelle;
B70 – chanterelle water blanched at 70°C temperature;
B80 – chanterelle water blanched at 80°C temperature;
B90 – chanterelle water blanched at 90°C temperature;
B100 – chanterelle water blanched at 100°C temperature.

All dried mushroom samples prior to analyses were ground in a blender to obtain fine powder of homogenous sample.

Analyses of physical parameters

Mushroom weight loss calculation was based on sample weight before and after blanching, when excess water was drained over a strainer for 5 minutes. For analysis of mushroom microstructure the samples were cut both from caps and stems in thickness of 5 μm. The fields observed under the microscope Axioskop 40 were fixed using a digital camera at 16 × 20 (VAREL contrast) or 16 × 40. At least ten measurements of the thickness of hypha were performed using Axiovision Le Rel 4.5. Colour was detected

using Colour Tec-PCM device. Colour components L*, a*, b* of each ground sample was measured at least in fifteen various points.

Analyses of chemical parameters

The ash content of mushrooms was determined by incineration at 550°C (Manjunathan & Kaviyarasan, 2011). Electrical conductivity in water extract was determined to characterise the total content of mineral substances using electrode TetraCon 325 connected to a conductometer inoLab pH/Cond 720 (WTW, Germany).

The protein amount in mushroom dry matter was determined by Lowry procedure (Lowry et al., 1951) using albumin as a standard.

Water extract for determination of total phenolic content, formol number, titratable acidity and electrical conductivity was prepared as follows: 1 g of powdered mushrooms was boiled in 50 ml of water for 30 min. The mixture was centrifuged (3000 × g, room temperature for 10 min) and supernatant portioned and kept frozen at -23°C until analysis.

The total content of phenolic compounds in water extract was determined by Folin-Ciocalteu assay. Gallic acid (0–0.75 mg ml^{-1}) was used as a standard to produce the standard curve. The absorbance of the reaction mixture was measured at 765 nm using UV/Vis spectrophotometer Jenway UV 6405. The total content of phenolic compounds was expressed as milligrams of gallic acid equivalents (GAE) per gram of mushroom dry matter (Barros et al., 2007).

Titratable acidity was determined by potentiometric titration as described previously (Tanner, 1987) and calculated as mmol of NaOH per 1 g of mushroom dry matter. The formol number was determined in water extract by potentiometric titration as described by Tanner (1987). Formol number was calculated as mmol of NaOH per 1 g of mushroom dry matter. Results of analysis were expressed per dry matter of samples.

Evaluation of rehydration capacity

Rehydration was carried out at controlled temperature of 55 ± 1°C. Samples were rehydrated by immersion of 5 g of each sample in 200 ml of distilled water for 7 hours. Evolution of sample weight was measured. Before weighing the sample, it was removed and allowed to drain over a mesh for 60 s in order to eliminate the superficial water. Each rehydration experiment was replicated twice; and the rehydration curves are plotted for kg moisture per kg dry matter versus time for each chanterelle sample.

Statistical analyses

The results are presented as the mean ± standard deviation. Data analysis was performed using in-built software of Microsoft Excel 2007. One-way analyses of variance (one-way ANOVA) were carried out to detect significant difference ($P < 0.05$) between the mean values that had more than two variables. For statistical analyses, ANOVA followed by *t*-test, Bonferroni's test or Kruskal-Wallis test followed by Dunn's test was used where appropriate, and the results for each experimental group were compared to the results of other groups. *P*-values of less than 0.05 were considered to be statistically significant. Statistical calculations were performed using Prism software (GraphPad, San Diego, CA, USA).

RESULTS AND DISCUSSION

Weight loss during blanching

In the blanching process mushroom weight loss was observed due to water and soluble solids diffusion into blanching medium. Results revealed that weight loss at 70–90°C was significantly smaller compared to blanching at 100°C temperature (Fig. 1).

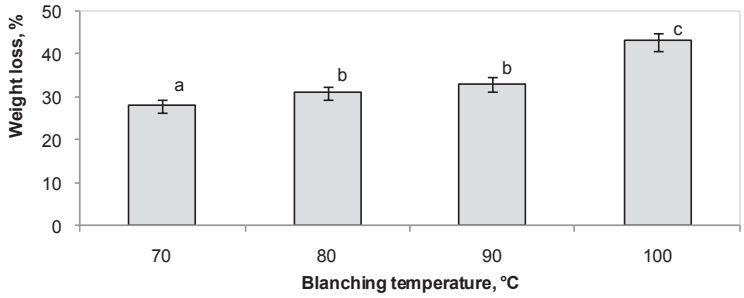

Figure 1. Mushroom weight loss in blanching process depending on temperature of blanching medium temperature. Note: the values marked with the same letter did not significantly differ ($P > 0.05$) among each other ($n = 5$).

Mushroom weight loss can be considered as beneficial because same water is removed and this decreases the amount of water to be evaporated during drying. Nevertheless it can have adverse effect on the chemical composition due to leakage of some valuable biologically active components such as minerals and soluble proteins.

Structure and colour

Technological processes – blanching and drying – has significant effect on changes in chanterelle microstructure, which influence physical and chemical properties of dried product. Images of fresh and microwave-vacuum dried chanterelle caps and stems were used for hypha thickness measurement. Measurement results of hypha thickness in the chanterelle stems are presented in Fig. 2, but in the caps in Fig. 3.

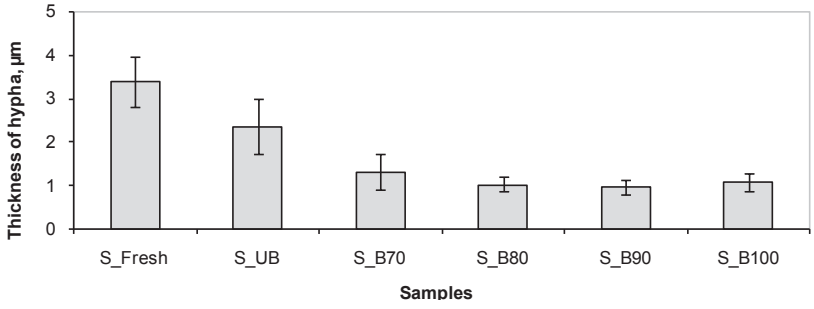

Figure 2. Hypha thickness of fresh (control) and microwave – vacuum dried chanterelle stems depending on the applied pre-treatment method: S_UB – unblanched; S_B70, S_B80, S_B90, S_B100 – blanched samples, where number of sample indicates blanching temperature.

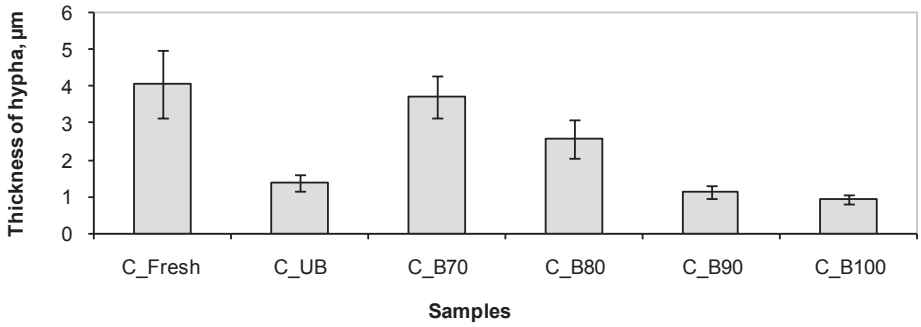

Figure 3. Hypha thickness of fresh (control) and microwave – vacuum dried chanterelle caps depending on the applied pre-treatment method: C_UB – unblanched; C_B70, C_B80, C_B90, C_B100 – blanched samples, where number of sample indicates blanching temperature.

The significant decrease of mushroom hypha thickness was observed for all dried samples due to moisture removal and subsequent shrinkage. The highest decrease both in stems and caps was observed in chanterelle dried after blanching at 90 and 100°C.

Significant difference ($P < 0.001$) in colour component L* of microwave vacuum dried chanterelle powder was detected among studied samples. The samples obtained from unblanched mushrooms or blanched at 100°C were significantly darker comparing to other samples (Table 2). However the darkest colour was found in chanterelle powder which was not blanched before drying. The same samples had more pronounced red colour component (a*), which generally gave a little orange shade to the samples. Colour component b*, which describe yellow colour, was not significantly different among studied samples ($P = 0.076$).

Table 2. Colour of microwave-vacuum dried chanterelle powder depending on the applied pre-treatment method

Samples	Colour components		
	L*	a*	b*
UB	52.65 ± 0.57 a[¥]	6.64 ± 1.80 a	29.13 ± 0.97 a
B70	69.67 ± 1.04 c	1.78 ± 0.36 b	31.07 ± 0.84 a
B80	70.88 ± 0.82 cd	1.84 ± 1.82 bc	29.28 ± 3.55 a
B90	72.37 ± 0.80 d	1.04 ± 0.94 c	28.92 ± 2.64 a
B100	57.22 ± 0.92 b	4.18 ± 0.87 d	29.57 ± 2.54 a

[¥] Data followed by different letters in the same column are significantly ($P < 0.05$) different among the applied pre-treatment; *t*-test ($n = 20$).

Colour components of microwave-vacuum dried chanterelle samples blanched at temperatures 70, 80 or 90°C had similar colour values, which significantly differed from those in samples – unblanched or blanched at 100°C. Mushrooms blanched at 70–90°C better retained brightness, which could be due to enzyme inactivation resulting from blanching compared to unblanched samples. It is in agreement with Bernas & Jaworska (2014) who revealed that the level of polyphenol oxidase activity showed a moderately negative correlation with L* and a* colour parameters. However blanching at 100°C can cause undesirable changes due to thermal effect. It is in agreement with Kotwaliwale et al. (2007) who indicated that colour changes during drying are mostly in

the form of browning caused by enzymatic or non-enzymatic reactions between carbohydrate and amino acids at elevated temperature.

Chemical parameters

The content of dry matter of chanterelle was 9.5 ± 0.5%. In the blanching process mushroom weight loss was observed due to diffusion of water and soluble solids into blanching medium. The results revealed that weight loss at 70–90°C was significantly smaller compared to blanching at 100°C temperature. The results indicated the tendency of smaller changes in microstructure, weight loss and colour for samples blanched at 70–80°C temperature comparing to the samples unblanched or blanched at higher temperatures.

Table 3. Chemical parameters of microwave-vacuum dried chanterelle

Samples	Electrical conductivity of mushroom water extracts, μS cm^{-1}	Titratable acidity, NaOH mmol g^{-1} DW	Formol number (FN), NaOH mmol g^{-1} DW	Total phenols (TP), mg GAE g^{-1} DW	Protein, g 100 g^{-1} DW
UB	2410	0.185	0.141	2.52	18.5 ± 0.9
B70	1711[a]	0.138[a]	0.102[a]	2.44[a]	17.3 ± 0.2
B80	1423[a,b]	0.084[a,b]	0.068[a,b]	2.20[a,b]	15.3 ± 0.7
B90	1127[a,b,c]	0.069[a,b,c]	0.068[a,b]	1.95[a,b,c]	15.0 ± 0.6
B100	1106[a,b,c]	0.055[a,b,c,d]	0.056[a,b,c,d]	1.75[a,b,c,d]	14.4 ± 0.7

Values are represented as average (n = 3; SEM values omitted for better clarity, except for protein); [a] indicates a significant difference from the UB group; [b] indicates a significant difference from the B70 group; [c] indicates a significant difference from the B80 group; [d] indicates a significant difference from the B90 group.
P-values of less than 0.05 considered to be statistically significant (ANOVA followed by Bonferroni's test, Kruskal-Wallis test for protein (n = 2)). No significant difference was observed for protein content.

The protein content in microwave-vacuum dried mushroom chanterelle was from 14.4 to 18.5 g 100 g^{-1} DW depending on the applied type of pre-treatment. At higher blanching temperatures lower protein content was observed probably due to the increased protein denaturation and increased diffusion of soluble components into blanching medium. Ash amount of chanterelle varied between 5.45 ± 0.02 g 100 g^{-1} and 9.89 ± 0.02 g 100 g^{-1} of mushroom dry matter, demonstrating decreasing tendency with increased blanching temperature. Electrical conductivity in water extract of microwave-vacuum dried chanterelle decreased with the increase in blanching temperature. The highest value was established for unblanched sample. The obtained result also indicates that the amount of strong electrolytes in chanterelle is high. However titratable acidity of chanterelle was significantly reduced after blanching due to leakage of soluble acids into blanching water.

Rehydration

The most intensive rehydration was observed within the initial period, but the rate slowed down gradually (Fig. 4) up to the saturation level. Similar results have been reported for rehydration characteristics of microwave-vacuum and convective hot-air dried mushrooms (*Agaricus bisporus*) (Giri & Prasad, 2007). Besides, it can be seen that

the rehydration ratio of blanched samples resulted in higher rehydration, compared to unblanched sample and sample blanched at 100°C.

For food preparation both the initial rehydration rate and the maximum water absorption are of importance. The maximum moisture content absorbed in rehydration process can be compared to the initial moisture content of 11.7 g moisture per gram of dry matter. Water recovery in dried samples depends on pre-treatment conditions.

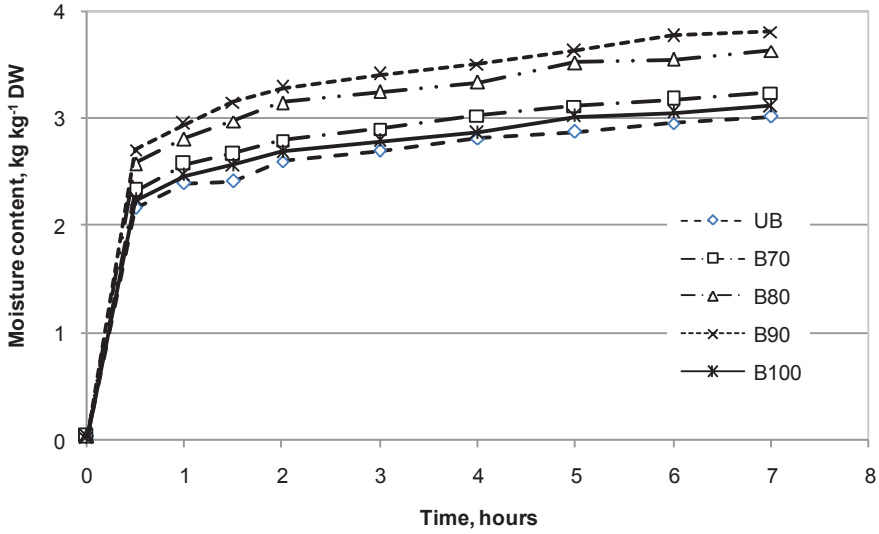

Figure 4. Rehydration properties of microwave-vacuum dried chanterelle: UB – unblanched; B70, B80, B90, B100 – blanched samples, where number of sample indicates blanching temperature.

Blanched samples have higher rehydration ratios compared to the unblanched sample. It coincides with findings of Doymaz (2014) who established that the rehydration ratio was observed to increase with increasing broccoli blanching temperature. If the water absorption was referred to the initial moisture content then microwave-vacuum dried sample pre-treated at 90°C recovered the highest amount (33%) among studied samples. Chanterelle samples which were not blanched or those blanched at 100°C recovered 26% and 27% of the initial available water, respectively. This might be due to the thermal destruction of cells during drying process.

CONCLUSIONS

Considering changes in chanterelle structure, colour, and rehydration properties the blanching temperatures of 70–90°C are the most suitable for pre-treatment of mushrooms prior to microwave vacuum drying, providing the best performance of dried product. Considering the chemical composition of dried samples it was established that unblanched product has the highest content of proteins, total phenols and other parameters, followed by the sample blanched at 70°C. Thus, blanching at 70°C is considered the most appropriate among studied, although further studies on quality changes during storage of dried product would be helpful.

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