Influence of Drying Procedure on Colour and Rehydration Characteristic of Wild Asparagus

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Abstract

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The objective of this research was to examine the influence of different drying procedures on the colour quality and rehydration capacity of wild asparagus (*Asparagus maritimus* L.). Wild asparagus samples were dried using convective (40°C, 50°C, 60°C, and 70°C at the airflow velocity of 2.75 m/s), natural, and freeze (–20°C and –40°C) drying procedures. Rehydration and colour characteristics were used as indicators of the quality of the dried asparagus samples. Convective drying of asparagus resulted in the smallest colour change of the fresh material, whereby drying at 60°C presented the optimum. The best rehydration ratio was achieved when the samples were freeze dried at –40°C. Naturally dried asparagus samples resulted in a very low rehydration ratio compared to the other procedures investigated. The rehydration and appearance of the dried asparagus are two important physical factors that need special attention when designing or selecting a drying procedure. Furthermore, the influence of drying on other quality characteristics of wild asparagus, such as the content of active ingredients or microbial count, should be investigated in further studies. The investigation of economic parameters of different drying procedures should be considered as well.

Keywords: wild asparagus; drying procedure; rehydration; colour

Asparagus maritimus L. is a rare wild species of asparagus growing in the Mediterranean region, morphologically similar to *A. officinalis*. Fresh asparagus is gaining popularity due to its unique texture and flavour (Lau *et al.* 2000). In some countries, it has been used as anti-cancer herbal medicine for a long time. Asparagus contains flavonoids (mainly rutin) and other phenolic compounds, which possess strong antioxidant properties (Nindo *et al.* 2003). Green asparagus is also an extremely perishable vegetable. Freshly harvested asparagus deteriorates rapidly which results in a short shelf life of 3–5 days under normal post-harvest handling at the room temperature (An *et al.* 2008). The very short shelf life of asparagus is mainly related to its high respiratory activity which continues after harvesting (Albanese *et al.* 2007). Dehydration, i.e. drying, of asparagus provides a long term conservation and marketability of this product.

Nowadays, food safety and quality, first of all the preservation of active ingredients, are strongly

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focused on by researchers, producers, processors, and consumers (Vadivambal & Jayas 2007). Good quality is judged by the freshness, expected appearance, flavour, and texture. Food safety characteristics are mostly defined by legislations – i.e. there are defined limits of undesirable impurities, chemical compounds, heavy metals, and microbial count. The changes in quality that can occur in any product during drying are those in its optical properties (colour, appearance), sensory properties (odour, taste, flavour), and structural properties (density, porosity, specific volume, textural properties, etc.). The correlation between the colour change and the loss of active ingredients (Müller 1992) has been confirmed on many medical and aromatic crops. The rehydration properties, rehydration rate, and rehydration capacity are important characteristics of many products, related to their later preparation for consumption (Krokida & Maroulis 2000). The products with a high rehydration capacity are tastier and retain their fresh appearance. The dominant conservation procedure of the wild asparagus is currently natural drying in the shadow, with draught or forced air flow. The greatest disadvantage of this process is the expected higher microbial count and the contamination with other impurities caused by insects, birds, etc.

Convective drying, mainly using tray driers, is also widely used, especially by small producers. This process can eliminate the disadvantages of the natural drying. Drying out to the desired level and achieving the equilibrium moisture content (Krokida & Marinos-Kouris 2003) is extremely difficult. Under- or overdrying is likely to occur. The consequence of underdrying, with the moisture content higher than equilibrium, results in a higher microbial count (Martinov *et al.* 2007). This procedure could also result in an undesirable reduction of active ingredients contents and inadequate rehydration characteristics. Freeze-drying is a dehydration process during which water is removed by sublimation of ice from frozen materials. As ice sublimes, the sublimation interface, which starts on the surface of the material, recedes and a porous shell of dried material remains. Vaporised water is transported through the porous layer of the dried material. Freeze-drying is the best method for drying food, if the quality of the final product is considered. Preservation of most of the initial raw material properties, such as appearance, taste, colour, flavour, texture, biological activity etc., makes it one of the best drying methods. The product also maintains its initial shape and dimensions. Therefore, the rehydration properties of the products are good. However, the vapour pressure driving force in freeze-drying is very low compared to conventional drying methods. This causes the drying time to be longer, which results in a relatively high cost of drying. For this reason, freeze-drying is likely to be economically viable only for expensive vegetables, like mushrooms or capsicum (George & Datta 2002).

The knowledge of the influence of drying on the food properties can be efficiently used to create new quality attributes and new functionalities for the final products (Lewicki 2006). Several studies have been carried out to investigate the drying characteristics of the *A. officinalis* (Strahm & Flores 1994; May *et al.* 1997; Nindo *et al.* 2003). However, there seems to be no published work on the drying behaviour of the wild asparagus (*Asparagus maritimus* L).

The objective of this investigation was to examine the influence of different drying procedures, convective drying, freeze drying, and natural drying, on the quality of dried wild asparagus. The colour of the dried material, material rehydrated after drying, and rehydration capacity were selected as the main quality characteristics.

MATERIAL AND METHODS

Fresh material. Fresh wild asparagus (*Asparagus maritimus* L.) plants were obtained from the area of the Adriatic Sea and stored at +4°C. After stabilisation at the room temperature, the asparagus samples were cut into 10 cm long slices. The dry matter content and colour of all samples were measured before and after drying.

Drying procedures – *Convective drying*. The asparagus samples were dried in a pilot plant tray dryer (UOP 8 Tray Dryer, Armfield, UK) (Figure 1). The dryer operates on thermogravimetric principle. The dryer enables the control of temperature and airflow velocity. The drying temperatures for non-treated asparagus samples varied in the range of 40°C, 50°C, 60°C, and 70°C. The dryer was operated at the air velocity of 2.75 m/s. The air flowed parallel to the horizontal drying surfaces of the samples. The drying process was started when the required drying conditions were achieved. Fifty asparagus samples were arranged on the trays

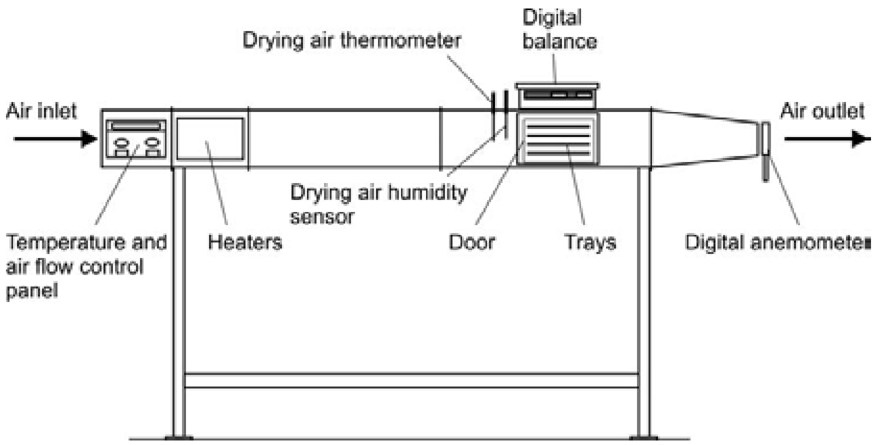


Figure 1. Laboratory dryer used for convective drying

and placed into the tunnel of the dryer, at which point the measurements were started. "Testo 350" probes, placed in the drying chamber, were used to monitor the relative humidity and air temperature (± 0.5°C). The airflow velocity was measured every five minutes with a digital anemometer (Armfield, UK) placed at the end of the tunnel. Dehydration lasted until the required moisture content of around 8% (wet base) was achieved.

Freeze drying – Asparagus samples were frozen at –20°C and –40°C and then freeze dried in a freeze-drying equipment (LIO-10P, Kambic d.o.o., Slovenia) operating at 0.5 mbar during the primary drying and at 0.03 mbar during the secondary drying. During, the primary drying, the shelf temperature was –5°C and rose continually to +20°C during the secondary drying. A temperature difference principal (sample temperature/shelf temperature) was used to determine the end of the primary drying.

Natural drying – Asparagus samples were evenly distributed on trays and dried in the shade at maximum daytime air temperature of around 22°C and minimum night temperature of approximately 9°C. Every hour the mass of the samples was measured on a digital scale until the required moisture content was achieved.

Determination of dry matter content. The dry matter content of the asparagus samples was determined by drying the milled samples (~10 g) for 24 h at 105 ± 0.5°C to a constant mass. Analyses were done using three samples of every category and the average dry matter content (w_{db}), expressed in percents (%), was calculated using the following equation:

$$w_{db}\ (\%) = \left(\frac{m_2}{m_1}\right) \times 100 \qquad (1)$$

where:
m_1 – mass of the sample before drying (g)
m_2 – mass of the sample after drying (g)

Colour measurement. The colour of fresh, dried, and rehydrated samples was measured using Chromameter CR-400 (Minolta). The asparagus slices were milled in a coffee grinder to obtain fine powder. The analyses of the colour values were done twenty times for each fresh and dried asparagus sample. Three parameters, L^* (lightness), a^* (redness), and b^* (yellowness), were used to study the changes in colour. L^* refers to the lightness of the samples and ranges from black = 0 to white = 100. A negative value of a^* indicates green, while a^* positive one indicates red-purple colour. A positive b^* indicates yellow colour and a negative one blue colour. The hue angle, defined as $h° = \tan^{-1}(b/a)$, was calculated from a^* and b^* values and expressed in degrees: 0° (red), 90° (yellow), 180° (green), 270° (blue). The total colour difference (ΔE) was calculated as follows:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (2)$$

$$\Delta L^* = L^* - L_0^* \quad \Delta a^* = a^* - a_0^* \quad \Delta b^* = b^* - b_0^* \qquad (3)$$

where:
L_0^*, a_0^*, b_0^* – colour parameters of fresh asparagus samples

Fresh asparagus samples were used as the reference while a higher ΔE represents a greater colour change from the reference material.

Rehydration ratio assessment. The rehydration capacity was used as a quality characteristic of the dried product (Velić *et al.* 2004) expressed in the rehydration rate – RR (Lewicki 1998). Approximately 2 g (± 0.01 g) of the dried sample was placed in a 250 ml laboratory glass (two analyses for each sample), 150 ml distilled water was added and the glass was covered and heated to boil within 3 minutes. The content of the laboratory glass was then gently boiled for 10 more min and then cooled. The cooled content was filtered for 5 min under vacuum and weighed. The dehydration ratio was calculated as:

$$RR = \frac{W_r}{W_d} \quad (4)$$

where:
W_r – drained weight (g) of the rehydrated sample
W_d – weight of the dry sample used for rehydration

Statistical analysis. One-way analysis of variance (ANOVA) and multiple comparisons (*post-hoc* LSD) were used to evaluate the significant differences of the data at $P < 0.05$. The data were expressed as means ± standard deviation. The experiments were replicated five times for statistical purposes.

RESULTS AND DISCUSION

Colour changes

The measured colour characteristics of the fresh material were: L^* 23.1, a^* –4.2 and b^* 8.7. The hue angle of the fresh material was 115.7°.

The effects of different drying procedures and temperatures on the colour values of the dried and rehydrated asparagus samples were found to be significant as shown in Table 1.

The colour characteristics are presented in Figures 2 and 3. The analysis showed a statistically significant influence of the drying procedure on total colour change with both the dried and rehydrated asparagus samples. The ANOVA analysis of total colour change of the dried asparagus samples showed the existence of five groups which differed significantly from one another ($P < 0.05$; *post-hoc* LSD) depending on the different drying procedures and temperatures. The results represented show that there were no statistically significant differences in the colour changes between convective drying at 50°C and 60°C and natural drying.

ΔE values of the rehydrated convectively dried samples varied from 3.4 to 8.2, whereas ΔE values of the rehydrated freeze dried samples varied from 10.3 to 14.9. ΔE value of the naturally dried sample was 5.5. The rehydrated convectively dried samples at –40°C revealed the highest hue angle value (110.8°) while the rehydrated freeze dried samples demostrated the highest total colour change in comparison to the rehydrated convectively and naturally dried samples. The ANOVA analysis of total colour change of the rehydrated asparagus samples showed the existence of six

Table 1. Colour parameters of dried and rehydrated asparagus samples using different procedures and temperatures

	Drying method	Temperature (°C)	L^*	a^*	b^*	$h°$
Dried samples	Convective air-drying	40	24.47 ± 0.31	−2.77 ± 0.27	6.95 ± 0.28	109.93 ± 1.26
		50	30.53 ± 2.25	−2.47 ± 0.84	8.48 ± 1.32	106.24 ± 2.91
		60	31.00 ± 1.20	−2.45 ± 0.36	8.49 ± 0.64	106.09 ± 1.20
		70	33.32 ± 0.34	−2.7 ± 0.10	9.9 ± 0.26	105.26 ± 1.23
	Freeze-drying	−20	40.89 ± 0.23	−5.36 ± 0.09	13.52 ± 0.11	111.63 ± 0.25
		−40	44.6 ± 0.31	−7.11 ± 0.12	14.92 ± 0.15	115.48 ± 0.51
	Natural drying	18	31.37 ± 0.21	−3.37 ± 0.11	10.36 ± 0.13	108.02 ± 0.70
Rehydrated samples	Convective air-drying	40	24.8 ± 0.16	−3.83 ± 0.06	10.09 ± 0.13	110.79 ± 0.21
		50	26.86 ± 0.36	−4.33 ± 0.09	11.71 ± 0.22	110.29 ± 0.26
		60	25.78 ± 0.22	−3.36 ± 0.09	10.75 ± 0.14	107.36 ± 0.29
		70	25.2 ± 0.29	−2.06 ± 0.13	10.46 ± 0.11	101.14 ± 0.64
	Freeze-drying	−20	30.99 ± 0.13	−2.52 ± 0.08	13.49 ± 0.10	100.58 ± 0.22
		−40	30.0 ± 0.11	−4.72 ± 0.08	13.67 ± 0.09	109.05 ± 0.28
	Natural drying	18	25.99 ± 0.10	−2.64 ± 0.30	11.11 ± 0.34	103.37 ± 0.34

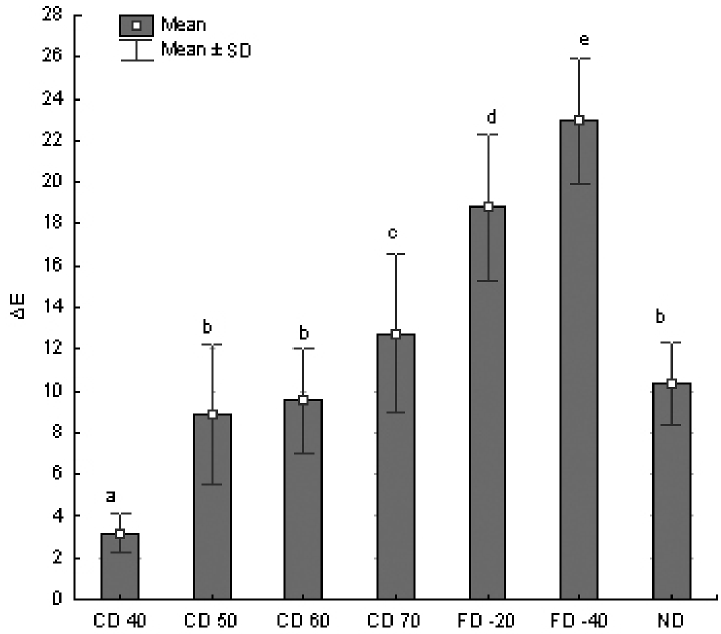


Figure 2. Colour difference (ΔE) of dried asparagus samples vs. different drying procedures and temperatures

CD – convective drying; FD – freeze drying; ND – natural drying

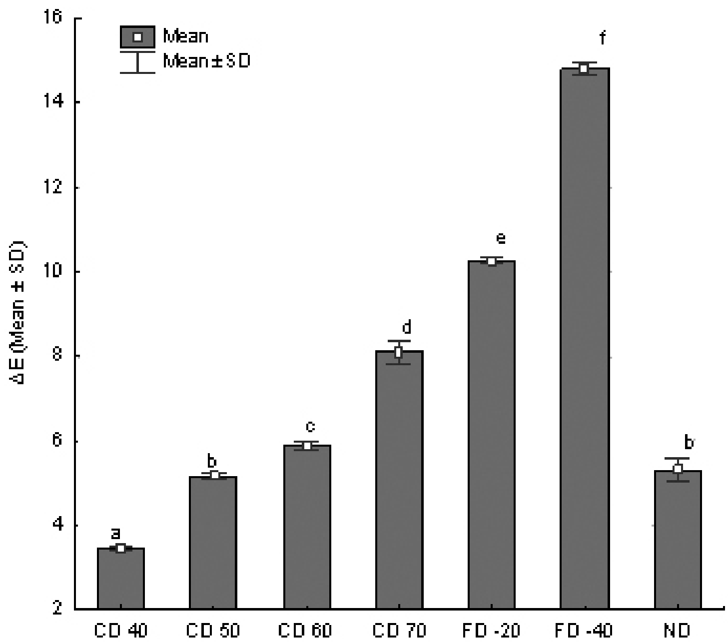
a, b, c, d, e, f – groups which differed statistically significantly ($P < 0.05$) from one another according to drying procedure

groups which differed significantly from one another ($P < 0.05$; *post-hoc* LSD) depending on the different drying procedures and temperatures. The results represented show that there are no statistically significant differences in the colour changes between the convective drying at 50°C and natural drying.

The drying procedure had a statistically significant effect on the asparagus colour, but the drying temperature was also a very important factor. In the case of convective drying, the increase of the drying temperature caused a greater colour change and resulted in darker colour. The measured reduction of the hue angle values, points to a decrease of the intensity of greenness and an increase of yellowness, which is in correlation with the reduction of total chlorophyll content.

Rehydration characteristics

The drying procedure had a statistically significant influence on the rehydration characteristic of the asparagus samples (Figure 4). In the case of convective drying, with the increase of the drying temperature the rehydration ratio for the



a, b, c, d, e, f – groups which differed statistically significantly ($P < 0.05$) from one another according to drying procedure

CD – convective drying; FD – freeze drying; ND – natural drying

Figure 3. Colour difference (ΔE) of rehydrated asparagus samples vs. different drying procedures and temperatures

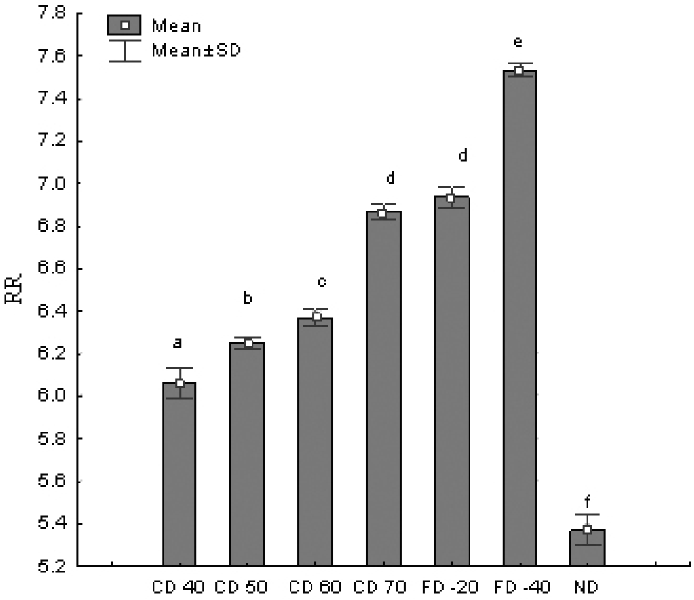


Figure 4. Rehydration ratio (RR) of non-treated asparagus samples vs. different drying procedures and temperatures

CD – convective drying; FD – freeze drying; ND – natural drying
a, b, c, d, e, f – groups which differed statistically significantly ($P < 0.05$) from one another according to drying procedure

non-treated asparagus samples also increased. It may have been due to the fact that the rate of the moisture removal at a higher drying temperature is very fast and causes less shrinkage of the dried samples. The rehydration ratio with the naturally dried samples was the lowest. Freeze drying at –40°C resulted in the highest rehydration ratio.

Convective drying at temperatures below 45°C results in a higher microbial count (Martinov *et al.* 2007). It means that the drying temperature should be above this level. Previous studies confirmed that a higher drying temperature results in a lower energy input (Müller 1992). Because of this and the very similar colour characteristics of the materials dried at 50°C and 60°C, optimal temperature is in this case is 60°C.

Consumers select their foods in supermarkets, primarily on the ground of visual perception, and this is often the only direct information received from the product. However, for a food technologist not only the colour, but also the rehydration capacity of the dried samples is important. Properties such as the rehydration capacity and colour of the rehydrated samples are more important, especially if dried asparagus is used, for example, in instant soup.

CONCLUSIONS

It is obvious that convective drying of asparagus results in the smallest colour change from the fresh material. The best colour characteristics were achieved at the drying temperature of 40°C. Due to the expected reduction of microbial count at the drying temperatures above 45°C, as is the case with other crops, the drying temperature should be above this level, although this presumption should be confirmed during future investigations. It is also well known that the increase of the drying temperature results in the reduction of the drying time and specific energy input. Because of that and the small difference in the colour characteristics obtained by drying at 50°C and 60°C, the higher value presents an optimum.

The rehydration characteristics of the freeze dried asparagus are significantly better in comparison to other methods, the best results having been achieved at –40°C.

Consumers prefer visible quality, i.e. the colour of the product. For some use, like soup, the rehydration characteristics should have the dominant role. This means that the food producers should decide upon the drying methods in accordance with the final use of the asparagus.

Future investigations should be given to the influence of drying on other quality characteristics of the wild asparagus, for example, the contents of active ingredients and microbial count. The investigation of the economic parameters of different drying procedures should be considered as well.

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