Vol. 8 (1999): 19–27.

Research Note

Infrared drying of herbs

Kirsti Pääkkönen
Department of Food Technology, PO Box 27, FIN-00014 University of Helsinki, Finland,
e-mail: kirsti.paakkonen@helsinki.fi

Jukka Havento
Agricultural Research Centre of Finland, Agricultural Engineering Research VAKOLA,
Vakolantie 55, FIN-03400 Vihti, Finland

Bertalan Galambosi
Agricultural Research Centre of Finland, Ecological Production, Karilantie 2 A, FIN-50600 Mikkeli, Finland

Markus Pyykkönen
Agricultural Research Centre of Finland, Agricultural Engineering Research VAKOLA,
Vakolantie 55, FIN-03400 Vihti, Finland

Drying experiments on peppermint (*Mentha piperita* L.), anise hyssop (*Agastache foeniculum* L.), parsley (*Petroselinum crispum* L.) and garden angelica (*Angelica archangelica* L.) were conducted using near infrared drying, operating at a product temperature of 35–50°C. The oil content, composition and residual water content of the dried herbs were determined. The microbiological quality of the fresh and the dried material was determined for total bacterial count and coliforms, moulds and yeasts. The results indicate that infrared radiation has potential for drying herbs since it is gentle and shortens the processing time.

Key words: *Agastache foeniculum*, *Angelica archangelica*, infrared dryers, *Mentha piperita*, microbial flora, *Petroselium crispum*, volatile compounds.

Introduction

Studies comparing infrared drying with techniques based on air convection show that the infrared radiation method is quicker than convection-based methods and that it is suitable if the processing time is a prime factor (Rao 1983, Navarri et al. 1992a,b, Dostie 1992). In convective drying the temperature of the solid is approximately limited to the wet bulb temperature of the drying air if no secondary heat sources are taken into account. In cases where the product temperature is lower than the boiling tem-

Manuscript received October 1998

perature, infrared radiation is shown to have no special influence on convective heat and mass transfer (Parrouffe et al. 1992). Since air is primarily a mixture of oxygen and nitrogen, neither of which absorbs infrared radiation, energy is transferred from the heating element to the product surface without heating the surrounding air (Jones 1992). To dry heat-sensitive particulate materials, a combined radiant-convective drying method or an intermittent irradiation drying mode must be applied (Zbicinski et al. 1992). In their study of the drying kinetics of mint, Lebert et al. (1992) showed that temperature is the main factor in controlling the rate of drying. The air temperature for herbs should be 40°C or even higher; parsley, for example, may be dried at an air temperature of 70°C without loss of oil or natural colour (Zaussinger 1994).

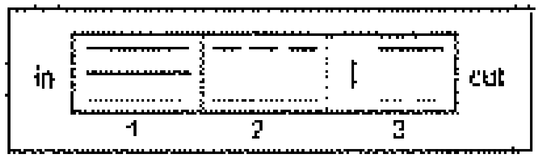

Fig. 1. An arrangement of infrared lamps seen from above.

Material and methods

Peppermint (*Mentha piperita* L.) originally from Bulgaria, anise hyssop (*Agastache foeniculum* L.) from Canada, parsley (*Petroselinum crispum* L.), the "common plain leaf" variety from Hungary, and garden angelica (*Angelica archangelica* L.) from Hungary were grown at Mikkeli, Finland. The peppermint and anise hyssop were harvested after blooming, the parsley and garden angelica at optimal bud formation and the roots of garden angelica from the crop of the first year.

The plant cuttings of peppermint, anise hyssop and parsley, and the leaves and roots of garden angelica were dried either immediately after harvesting or, in the case of some samples, within one day.

Infrared dryer

A prototype wooden static bed dryer in which the drying air is blown through the bed of the particles to be dried was built for the experiments by Agrodry Co, Lahti, Finland. The overall dimensions of the triple chamber system were 6 m x 1.2 m x 1 m and the inner dimensions were 6 m x 1 m x 0.75 m. The upper part, side walls and bottom of the container were covered with plywood, and the inside of the container was lined with aluminium sheets to reflect infrared radiation. The samples were placed on nine steel mesh trays, 0.9 m x 0.6 m x 0.1 m in size. Each batch of plant material weighed 13.5 kg (2.78 kg/m^2). The trays were set on a chain conveyor for loading and unloading. Three air intake openings were constructed in the roof of each chamber (0.8 m x 0.1 m), and an air exhaust opening (0.40 m x 0.23 m) was located in the middle of each bottom sheet. There were twelve blowers (Papst Typ4656N, 19 W) on each side of the chain conveyor. The air flowed into the empty dryer at a rate of 580 m^3/h. The near infrared panel heater was composed of eleven lamps, 500 mm, 1000 mm and 1500 mm in length, with a spectrum ranging from a wavelength of <2 µm to 4–5 µm. The lamps were hung at a distance of 100 mm from the roof. Figure 1 shows the arrangement of the lamps in the chambers. The radiation cycles could be adjusted separately for chamber 1, and for chambers 2 and 3. The nominal power of each chamber was 13 kW, 9 kW and 9 kW, respectively.

Drying experiments

The drying rate was deduced from the weight loss of the sample determined with an electric balance (Mettler PE16). The moisture content of the fresh herbs and, separately, of the dried leaves and the dried stipes was determined by keeping the material in an oven at 105°C for at least 14 h

Vol. 8 (1999): 19–27.

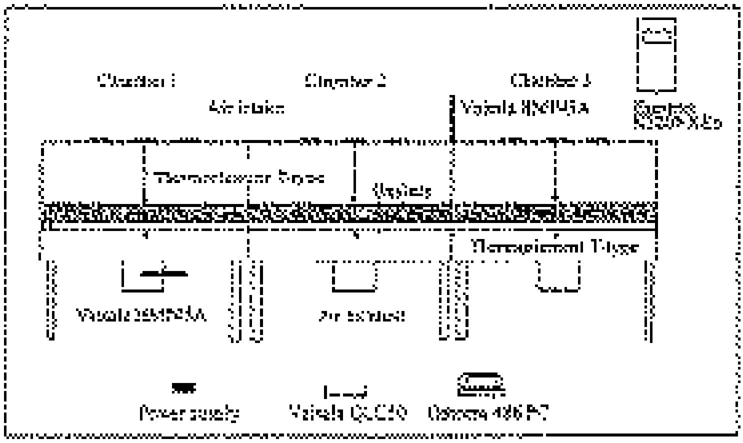

Fig. 2. Measuring system for continuous data acquisition and sensor positions.

and weighing it to constant weight. A small part of the sample was dried in the oven at 40°C for 2 or 3 days to be used for oil and microbiological analyses for comparison purposes. The essential oils from homogenized dry herbs were obtained in 2 h with a Karlsruher distillation apparatus and the volume of distillate was measured in two replicates. The composition of the oils was determined by gas chromatography-mass spectrometry (GC-MS) analyses. GC-MS was performed on an HP 5890 GC coupled to an HP 5970 quadrupole mass spectrometer operating at an ionization voltage of 70 eV and an electron multiplier voltage of 1600 V. The column used was a fused silica NB-351, 25 m x 0.20 mm i.d., phase thickness 0.2 µm (Nordion Instruments, Helsinki, Finland). The oven temperature was programmed for 60–210°C at 6°C/min, and helium was used as carrier gas at a flow rate of 0.5 ml/min. The injected sample volume was 1 µl. Identification was based on the GC retention times of authentic samples and GC-MS spectra and retention times of previously analysed samples stored in the database. The components were identified with a correlation coefficient of 95–99%. The microbiological quality of the fresh and dried material was determined for total bacterial count according to ISO 4833/91; coliforms were determined according to ISO 4832/91 and moulds and yeasts according to NMKL 98/95.

Monitoring

The operation of the dryer was monitored continuously for the period of the experiment with an Osborne NB4S-25. The temperatures and humidities of the intake and exhaust air were measured with Vaisala HMP45A sensors. Six thermoelements measured throughout the drying process temperature changes inside the chambers. Three copper-constantan thermocouples placed horizontally at 3–4 mm from the surface of the herbs gave the inner temperature of the thin layer. Exhaust air flow was recorded with a Halton MSD125 meter using an Alnor MP3KDS micromanometer. Electrical power was measured with an Enermet K320NXEp meter. The schematic diagram of the experimental test section is shown in Fig. 2.

Results and discussion

In convective drying, the heat-transfer coefficient is directly related to the air velocity and depends on temperature and humidity. When infrared radiation is used, the main parameter is the incident infrared flux. According to Dostie (1992), up to 75% of water can be removed by

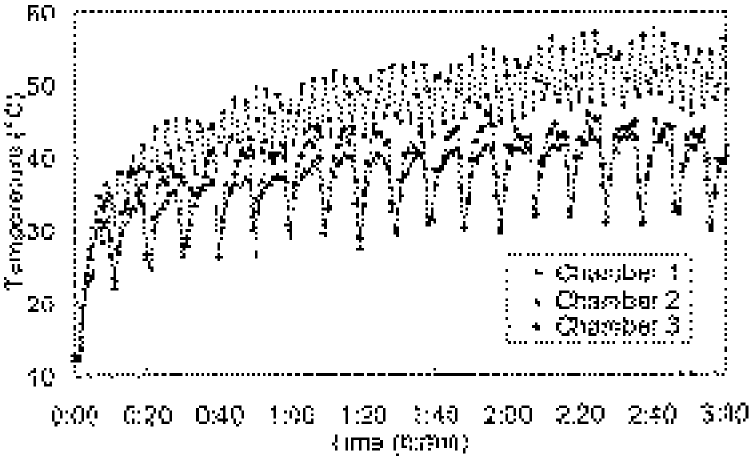

Fig. 3. Temperature gradient in the drying chambers during dehydration of parsley.

infrared radiation without product degradation. In our experiments using intermittent irradiation the periods of radiation were alternated with periods of tempering with air. During the cooling periods the temperature gradient within the material changed direction, and the displacement of moisture towards the evaporation zone intensified. The drying experiments were performed as a function of three main operating parameters, namely, infrared power duration, drying time and energy consumption. The temperature depended on the intensity of the infrared radiation. The timing of irradiation periods (on/off) in chamber 1 differed from that in chambers 2 and 3, where the irradiation period was relatively long and varied, depending on experimental conditions. The temperature gradient in the drying chambers during dehydration of parsley is shown in Figure 3. The temperature difference between chambers 1 and 2 was about 10°C. The arrangement of the lamps affected the temperature. In chamber 3, for example, one of the lamps was placed crosswise (Fig. 1) and the temperature was lower than in chamber 2, where the lamps were in a linear array. Correspondingly, herbs dried more rapidly in chamber 1 than in chamber 2, and most slowly in chamber 3. For a given temperature, the cooling effect of convec-

Table 1**.** Temperature and humidity of intake air during drying experiments.

Plant		Temperature Mean value °C	Standard deviation °C	Humidity Mean value %	Standard deviation %
Peppermint	A*	27.0	0.9	48.4	3.5
	B	29.0	0.4	40.8	1.2
Anise hyssop	A	18.0	0.6	37.7	2.5
	B	13.7	3.0	64.0	8.5
Parsley	A	15.2	1.4	72.6	5.8
	B	19.4	0.8	52.1	4.9
Garden angelica	A	7.4	0.5	80.0	6.7
(leaves)	B	6.5	1.8	67.6	7.6
Garden angelica	A	9.8	0.8	68.2	2.4
(roots)	B	9.2	1.2	81.3	3.3

* A and B are two different experiments

Vol. 8 (1999): 19–27.

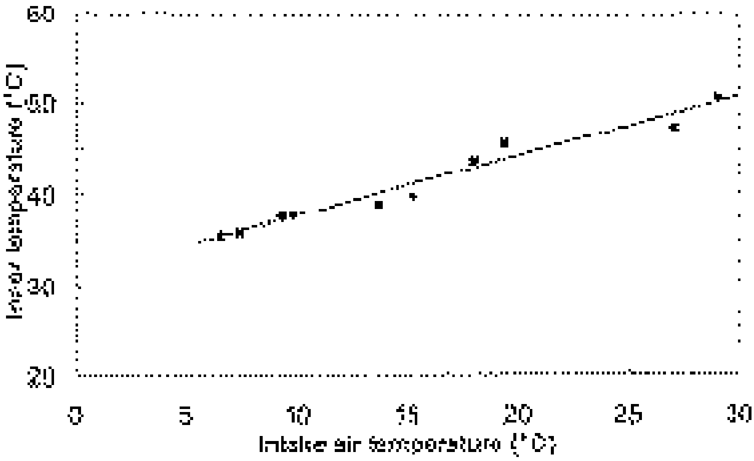

Fig. 4. Mean values of inner temperatures in the dryer as an overall function of intake air temperature.

tion allows higher radiative conditions and shorter drying times. At the time of year of our experiments air temperature and humidity varied considerably (Table 1). Figure 4 shows the mean temperature inside the dryer as a function of intake air temperature. Table 2 gives the mean values of the drying parameters and the results of the experiments: timing of irradiation, drying temperature and time, moisture content measured separately for leaves, stipes and roots, energy consumption, drying rate and volume of air flow. Temperature was the main factor in drying rate. At the highest drying temperature (peppermint), the energy consumption per unit of evaporated water was the lowest. Water turned out to be much easier to remove from the leaves than from the stipes of the herb plants (cf. Patil and Sokhansanj 1992). After very short drying times

Table 2. Results of infrared drying experiments**.**

Plant		Timing on:off 1[1] (min)	Timing on:off 2, 3 (min)	Drying time (h)	Moisture, fresh plants (%w/w)	Moisture, dried leaves (%w/w)	Moisture, dried stipes (%w/w)	Inner temperature[2] (°C) Mean	Inner temperature[2] (°C) SD	Energy consumption (kWh/kg H_2O)	Drying rate (kg H_2O/h)	Volume flow (m^3/h)
Peppermint	A*	1.5:1.5	4:1.5	2.25	75.9	13.0	39.5	47.5	5.0	3.15	4.00	542
	B	1.5:1.5	4:1.5	2.25	75.9	11.8	37.3	50.9	5.0	3.13	4.09	541
Anise hyssop	A	1.7:1.7	8:1.5	3	74.9	8.7	28.8	43.8	5.6	4.81	3.11	550
	B	1.7:1.7	8:1.5	3	71.7	12.0	33.8	39.0	7.1	5.30	2.74	556
Parsley	A	1.7:1.7	8:1.5	3	85.0	13.2	52.2	39.9	5.9	4.19	3.41	549
	B	1.7:1.7	8:1.5	3	84.8	7.8	45.0	45.6	6.4	4.02	3.59	549
Garden angelica	A	1.7:1.7	10:0.75	3.5	86.3	7.4	55.0	35.9	5.8	5.36	2.90	548
(leaves)	B	1.7:1.7	10:0.75	3.5	86.1	6.2	62.5	35.5	7.0	5.40	2.92	551
Garden angelica	A	1.5:1.7	10:0.75	3.5	79.5	9.4	32.3	37.8	6.2	5.32	2.92	539
(roots)	B	1.5:1.7	10:0.75	3.5	77.5	9.5**	27.4***	37.6	6.4	5.30	2.90	552

[1] Chamber numbers.
[2] Mean value and standard deviation for all chambers measured on the above plants.
* A and B are two different measurements.
** Final moisture measured on fine roots.
*** Final moisture measured on rough roots.

Table 3. Number of microflora in fresh herbs per gram and after electric oven drying at 40°C and infrared drying. Two samples were taken from each herb.

		APC[1]	Coliform	Moulds	Yeasts
Peppermint					
Fresh		7.8×10^7	2.7×10^5	3×10^4	1.2×10^5
Oven-dried	A*	3.4×10^6	2.1×10^5	2×10^4	8.5×10^4
	B	4.8×10^7	3×10^4	3.9×10^4	2.3×10^4
IR-dried	A	3.9×10^5	<10	6×10^2	7×10^2
	B	1.3×10^6	4.3×10^3	5×10^3	1×10^4
Anise hyssop					
Fresh		1.1×10^6	<100	1×10^4	
Oven-dried	A	9.2×10^7	3.5×10^3	1.8×10^5	9.2×10^5
	B	4.5×10^6	1×10^5	2.2×10^5	8×10^5
IR-dried	A	1.2×10^6	<10	4×10^3	1×10^5
	B	1.6×10^6	<10	3.6×10^4	1.2×10^5
Parsley					
Fresh		1.7×10^6	3.7×10^4	2.3×10^4	8.8×10^4
Oven-dried	A	1.6×10^7	3×10^5	1.8×10^4	7.2×10^4
	B	1.7×10^7	1.7×10^5	5×10^3	5.7×10^4
IR-dried	A	5.3×10^6	5×10^3	7×10^3	4.2×10^4
	B	4×10^6	5×10^3	1.1×10^4	4×10^4
Garden angelica (roots)					
Oven-dried	A	3.4×10^7	4×10^5	1×10^4	4×10^3
	B	1.7×10^7	1.8×10^5	1×10^3	3×10^3
IR-dried	A	8.5×10^5	8×10^3	3×10^3	5×10^3
	B	1.3×10^5	<10	1.5×10^3	1×10^2
Garden angelica (leaves)					
Oven-dried	A	7.2×10^6	4×10^5	2.3×10^4	2.2×10^4
	B	1.5×10^8	1.2×10^5	1.6×10^4	9×10^3
IR-dried	A	1.6×10^6	1.3×10^3	3.8×10^4	4.5×10^4
	B	1.1×10^6	1.2×10^4	2.2×10^4	3.8×10^4

[1)] Aerobic plate count
* A and B are two different samples

(2.5–3.5 h) the water content of the leaves was about 10%, but that of the stipes was much higher, over 30%. To optimize the drying process in terms of drying time and initial moisture content, it is therefore essential that herb plants should be graded before drying.

When herbs are dried, the maximum temperature relating to the plants is a very important variable. Here, drying temperature and rate depended on the incident infrared radiation effectively absorbed by the sample. Low temperature drying with infrared radiation normally requires a thin layer bed and large drying areas if a proper quality of dried material is to be achieved.

The poor microbiological quality of the fresh herb samples (Table 3) was most likely due to the late harvest time or the inadequate harvesting technique (cf. Deans et al. 1991, 1988). The drying experiments with peppermint, anise hyssop and parsley revealed that the aerobic plate count (APC) of the electric oven-dried samples did not differ from that of the infrared-dried samples. The drying experiment with garden angelica showed that the APC of the roots was about

Vol. 8 (1999): 19–27.

Table 4. Drying conditions and oil contents of dried plant samples.

Plant	Drying temperature °C	Drying time h	Total oil % w/w	SD[1] % w/w	Total amount of aroma compounds[2] % w/w
Peppermint					
Oven-dried	40	48	1.23	0.33	74.22
IR-dried	45	3	1.09	0.04	80.34
Anise hyssop					
Oven-dried	40	48	0.50	0.06	96.69
IR-dried	41	3	0.48	0.06	90.72
Parsley					
Oven-dried	40	72	0.18	0.02	58.68
IR-dried	43	3	0.27	0.02	65.81
Garden angelica (roots)					
Oven-dried	40	72	0.28	0.13	50.69
IR-dried	38	3.5	0.42	0.12	45.25
Garden angelica (leaves)					
Oven-dried	40	24	0.09	0.02	
IR-dried	36	3.5	0.09	0.01	

1) Standard deviation
2) Calculated from total oil

100 times higher after electric oven than after infrared drying, but no differences were noted among the leaves. The number of coliforms was lower in infrared than in electric oven drying, although the mould and yeast counts did not differ. Results indicated that drying methods in general did not affect the microbial quality of herbs.

Oil content of the herb plants was mainly affected by the varying in growth sequences during summer and autumn but also by the difference in growing years (Shalaby et al. 1988a,b). The total oil contents of peppermint and anise hyssop did not differ clearly whether dried with infrared radiation or in the electric oven (Table 4). The compounds shown in Fig. 5 are typical of the oils analysed. The characteristic aroma of a plant is mainly due to the presence of one or a few main components of the essential oil. The aroma of peppermint, for examle, is mainly due to the presence of menthol and menthone. The proportion of menthol was slightly higher in peppermint dried with infrared radiation than in the electric oven, similarly, the proportion of menthone in anise hyssop and the total oil content of parsley were clearly higher. The proportion of myristicine in parsley was twice as high in infrared as in electric oven drying. The total oil content of garden angelica roots was clearly higher in infrared than in oven drying; however, only the proportion of terpinen-4-ol was higher in the infrared-dried samples. No differences were observed in the total oil contents of garden angelica leaves dried by the different methods. GC analysis revealed a minor difference in volatile oil content between oven-dried and infrared-dried herb samples when the drying time in the oven was 2 days. With an oven-drying time of 3 days, a perceptible difference was noted between this drying period and short-term (3.5 h) infrared drying.

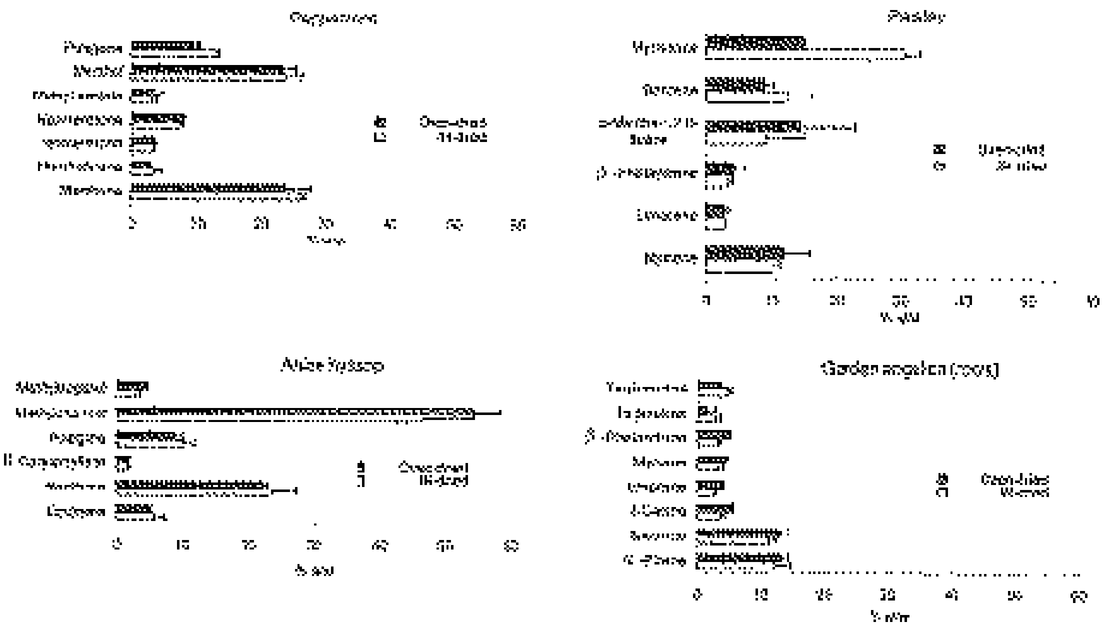

Fig. 5. Effect of drying method on aroma compounds of plants.

Conclusions

The original fresh material was the essential factor determining the quality of dried herbs. Nevertheless, the drying method clearly affected microbial quality.

Results indicated that the drying method affects the composition of the volatile oils in dried herbs. Consequently, a combined infrared-convection process is a potentially useful method for drying herbs, giving high drying rates at low drying temperatures. Herb plants must, however, be graded for the drying process to be effective.

References

Deans, S.G., Svoboda, K.P. & Bartlett, M.C. 1991. Effect of microwave oven and warm-air drying on the microflora and volatile oil profile of culinary herbs. Journal of Essential Oil Research 3: 341-347.

–, Svoboda, K.P. & Ritchie, G.A. 1988. Changes of microflora during oven-drying of culinary herbs. Journal of Horticultural Science 63: 137–140.

Dostie, M. 1992. Optimization of a drying process using infrared, ratio frequency and convection heating. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 679–684.

ISO 1991. The International Organization for Standardization 4832/91, 4833/91.

Jones, P. 1992. Electromagnetic wave energy in drying processes. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 114–136.

Lebert, A., Tharrault, P., Rocha, T. & Marty-Audouin, C. 1992. The drying kinetics of mint (Mentha spicata Huds.). Journal of Food Engineering 17: 15–28.

Navarri, P., Andrieu, J. & Gevaudan, A. 1992a. Studies on infrared and convective drying of non hygroscopic solids. In: Mujumdar, A.S. (ed.). Drying '92. Else-

Vol. 8 (1999): 19–27.

vier Science Publisher B.V. p. 685–694.

–, Gevaudan, A. & Andrieu, J. 1992b. Preliminary study of drying of coated film heated by infrared radiation. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 722–728.

NMKL 1995. Nordic Committee on Food Analysis (Nordisk Metodik-Kommitte för Livsmedel) 98/95.

Parrouffe, J.-M., Dostie, M., Mujumdar, A.S. & Poulin, A. 1992. Convective transport in infrared drying. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 695–703.

Patil, R.T. & Sokhansanj, S. 1992. Drying rates of alfalfa components. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 1850–1857.

Rao, P.N. 1983. Effectiveness of infrared radiation as a source of energy for paddy drying. Journal of Agricultural Engineering 20: 71–76.

Shalaby, A.S., El-Gamasy, El-Gengaihi, S.E. & Khattab, M.D. 1988a. Post harvest studies on herb and oil of Mentha arvensis, L. Egyptian Journal of Horticulture 15: 213–224.

–, El-Gamasy, A.M. Khattab, M.D. & Oda, H.S. 1988b. Changes in the chemical composition of Mentha piperita and Mentha viridis during storage. Egyptian Journal of Horticulture 15: 225–240.

Zaussinger, A. 1994. Convective drying of herbs. In: Workshop "Post harvest handling of medicinal plants". Dusseldorf, 3.9.1993. Gesellschaft fur Arzneiplanzenforschung. p. 5–29.

Zbicinski, I., Jakobsen, A. & Driscoll, J.L. 1992. Application of infra-red radiation for drying of particulate materials. In: Mujumdar, A.S. (ed.). Drying '92. Elsevier Science Publisher B.V. p. 704–711.

SELOSTUS

Yrttien infrapunakuivaus

Kirsti Pääkkönen, Jukka Havento, Bertalan Galambosi ja Markus Pyykkönen

Helsingin yliopisto ja Maatalouden tutkimuskeskus

Yrttien kuivaukseen rakennettiin kuivuri, jonka runkorakenne oli puuta ja joka oli vuorattu kiillotetulla alumiinipellillä sisältä ja vanerilla päältä. Kuivaustunneli oli jaettu kolmeen peräkkäiseen kammio-osaan, joiden kattoon oli ripustettu erikokoisia infrapunalamppuja (500 mm, 1000 mm ja 1500 mm) tunnelin pitkittäissuuntaisesti ja lisäksi kammiossa 3 yksi lampuista poikittaissuuntaisesti. Nimellistehot peräkkäisissä kammioissa olivat 13, 9 ja 9 kW. Kuivattavat kasvit asetettiin yhdeksään teräsverkkokoriin, joiden yhteistilavuus oli 486 dm^3 ja jotka siirrettiin kuivaukseen ja kuivurista ulos sähkömoottorikäyttöisellä kuljetinradalla. Kuivausilma kulki kuivattavan massan läpi ylhäältä alaspäin ts. kammioiden välipohjassa oli puhaltimet ja kattolevyissä imuaukot. Kussakin kammiossa oli oma ilmanpoistokanavansa.

Kokeissa kuivattiin piparminttua, anisiisoppia, persiljaa sekä väinönputken lehtiä ja juuria. Kasvit kuivattiin silputtuna massana, jota kuivattiin kerralla 10–30 kg. Kuivatusta massasta seulottiin erilleen lehdet ja varret.

Säteilyteho ja säteilyelementtien suunta vaikuttivat kuivumisnopeuteen. Kuivuminen oli nopeinta ensimmäisessä kammiossa ja hitainta viimeisessä kammiossa. Kuivauslämpötilan nostaminen pienensi energian kulutusta kuivauksessa. Silputtujen yrttien lehdet kuivuivat 35–50°C:ssa noin 10 % vesipitoisuuteen keskimäärin kolmessa tunnissa, mutta varret jäivät vielä märiksi. Infrapunatekniikkaa käytettäessä kasveista tulee ilmeisesti poistaa varsiosat ennen kuivausta, jotta lopputuote täyttäisi kuivatulle tuotteelle asetetut laatuvaatimukset. Eteeristen öljyjen pitoisuus oli hiukan korkeampi infrapunakuivatuissa yrteissä kuin 40°C:ssa uunissa 3 päivää kuivatuissa vertailunäytteissä. Koliformien pitoisuus oli vähän pienempi infrapunakuivatuissa yrteissä kuin uunissa kuivatuissa yrteissä. Homeiden ja hiivojen pitoisuudessa ei juurikaan ollut eroja. Tutkimuksen tulokset osoittavat, että infrapunakuivaus on yrttien kuivaukseen soveltuva menetelmä.