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Changes in the Chemical Composition of Basil Caused by Different Drying Procedures

LUIGI FRANCESCO DI CESARE,* ELISABETTA FORNI, DANIELA VISCARDI, AND RENATO CARLO NANI

IVTPA, Via G. Venezian 26, 20133 Milan, Italy

Basil (*Ocimum basilicum* L.) leaves were dried using a microwave oven at atmospheric pressure or two traditional methods: air-drying at 50 °C and freeze-drying. The microwave-drying was carried out at different powers and times on raw basil leaves, while for air and freeze-drying techniques, both raw and blanched leaves were used. The raw and dried basil was analyzed for selected aroma compounds by gas chromatography/mass spectrometry−selected-ion-monitoring , the chlorophyll a and b by HPLC and the color by a reflected-light colorimeter. For dried samples microwaved for 1 min at 270, 2 min at 440, 1 min at 650, and 1 min at 1100 W, the percentage retentions of the characteristic volatile compounds (eucalyptol, linalool, eugenol, and methyl eugenol) were higher than in the samples dried by traditional methods, with the exception of freeze-dried unblenched basil. Microwave drying allowed a larger retention of chlorophyll pigments than air-drying and freeze-drying (with or without blanching) and preserved the color of the raw basil. Microwave drying requires a much shorter treatment and implied the simultaneous blanching of the material.

KEYWORDS: Basil (*Ocimum basilicum* L.); microwave drying; air-drying; freeze-drying; volatile compounds; chlorophylls; color

INTRODUCTION

The food industry is becoming increasingly interested in aromatic herbs and spices. These are used not only for flavoring but also for other purposes, including their medicinal and antiinflammatory properties or their antioxidant activities (*1*−*3*). Basil is a popular aromatic and annual herb growing in many regions of the world. Immediately after harvesting, this highly perishable raw material has to be preserved against deterioration and spoilage. Drying is by far the most widely used treatment, but must be performed carefully so as to preserve the aroma and color of the raw material as much as possible (*4*). Many studies concerning the volatile composition of basil leaves have been carried out. Linalool and methylchavicol are the most important compounds in Egypt basil (*5*), while linalool, methylchavicol, and eugenol are the main components in Israel basil (*6*). The major components of the Fijian *Ocimum basilicum* L., studied by Brophy et al. (*7*), are methylcinnamate, linalool, methyleugenol, and eugenol. According to Nykänen (*8*), the essential oil from Finland basil is rich in methylchavicol and linalool, while that from *Ocimum basilicum* L., cultivated in Taiwan, contains large amounts of methylchavicol (*9*). The investigation by Di Cesare et al. (*10*−*14*), about the volatile compounds from *Ocimum basilicum maximum* L. cv. di Genova grande verde, cultivated in Liguria (Italy), showed that the main components are eucalyptol, linalool, eugenol, and methyleugenol, while methylchavicol, which is a common aroma compound in many other basil essential oils, is not present in the basil from Liguria as well as from other Italian regions.

The loss of green color is mainly due to the degradation of chlorophyllic pigments. Degradation of chlorophyll a and b during thermal processing produces color changes from a bright green color to the olive brown color of pheophytins a and b, due to the loss of Mg^{2+}. The major green pigment, the blue-green colored chlorophyll a (Chl a) is less stable than the yellow-green chlorophyll b (Chl b) so, in heat damaged products, the Chl a/Chl b ratio decreases and the color shifts from green-blue green to green-yellow green. Another possible pathway for chlorophyll breakdown is the loss of phytol, catalyzed by chlorophyllase, with formation of chlorophyllides, which are more sensitive than chlorophylls to the loss of Mg^{2+} (*15*). As a function of drying conditions, the development of brown pigments is observed (*16*). As the leaf is heated, the intercellular spaces collapse, liberating plant acid compounds and releasing chlorophylls from the protein complex. These events promote the change of chlorophylls into pheophytins, providing a substrate for the enzymatic browning. Blanching treatments, before freezing or drying, limit damages related to the color, but produce loss of aroma compounds (*17*, *18*). Other authors (*19*) reported that the best way to preserve full flavor and an attractive green color should be a drying temperature near 60 °C, preferably starting from blanched basil. Steam blanching coupled with a low air-drying temperature like 35 °C was

* Author to whom correspondence should be addressed. Tel.: +039 02 2395571. Fax: +039 02 23365377. E-mail: ivtpa@interbusiness.it or dicesare.ivtpa@interbusiness.it.

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Table 1. Operative Conditions for Microwave Drying of Basil *O. basilicum* L. Leaves

	operative conditions			dry matter
test	power (watt)	power (%)	time (min)	% ± SD
A	270	25	1	94.89 ± 1.12
	440	40	1	
	1100	100	3 (5)[a]	
B	270	25	1	95.18 ± 2.16
	440	40	2	
	1100	100	2 (5)[a]	
C	270	25	1	90.78 ± 1.05
	440	40	2	
	650	60	1	
	1100	100	1 (5)[a]	
D	270	25	1	89.78 ± 1.98
	440	40	2	
	880	80	1	
	1100	100	1 (5)[a]	
E	270	25	1	91.60 ± 2.00
	440	40	1	
	650	60	1	
	880	80	1	
	1100	100	1 (5)[a]	
F	270	25	1	93.48 ± 1.64
	440	40	2	
	880	80	2	
	1100	100	1 (6)[a]	

[a] Total drying time.

proposed (*20*) to preserve color and chlorophylls. In the basil leaves blanched before air- or freeze-drying, the Chl a/Chl b ratios were slightly higher than in unblanched samples, and a lower saturation was obtained for air-drying. A comparative research on different drying methods (*21*) reported that both color and taste of freeze-dried basil are better than those of unblanched air-dried basil.

Freeze-drying (which does not imply heat damages but is a costly process) and microwave-drying are alternative ways to improve the quality of dehydrated products. Microwave energy trasfer causes a rapid evaporation of water from the vegetable tissue: treatment time is shorter and oxidation is limited with a substantial preservation of color, flavor, and sensory qualities of products. As a further improvement, vacuum-microwave-drying was proposed (*22*). A comparison between air-drying and vacuum-microwave-drying showed that better results, both for color and flavor preservation, can be obtained with the latter technique (*22*). More recently, the two step treatment, namely air-drying followed by microwave-drying, has met with some interest (*23*). The early air-drying removes the moisture from the surface of the basil leaves, while microwave heating acts on the water linked to the vegetable tissue.

The present research reports a comparative study about the content of the volatile compounds and chlorophyll pigments in microwave-dried, air-dried and freeze-dried basil leaves.

MATERIALS AND METHODS

Plant Source. Basil plant (*O. basilicum* L.) was purchased from a local market. In all the experiments, the leaves were detatched from the stems and carefully selected before use. Dry matter was 6.64% ± 0.27.

Microwave-Drying. Samples (18 g) of raw basil leaves were placed onto a glass fiber sheet in a China plate and then dried in a microwave oven (MDS 2100-CEM Italia) at atmospheric pressure. Microwave power and drying time are reported in **Table 1** together with the final dry matter of the samples.

Air-Drying. Samples (18 g) of raw and blanched (boiling water for 20 s) basil leaves were air-dried in an alternative upward−downward air circulating drier pilot plant (Thermo Lab., Lodi, Italy). The drying temperature was set at 50 °C, with a 1.5 m/sec air flow. The drying process was carried out for 4.5 h on raw leaves (R50) and for 3 h on blanched leaves (B50) to attain comparable dry matter (96.90% ± 2.31 and 94.42% ± 2.45 for R50 and B50, respectively).

Freeze-Drying. A freeze-drier pilot plant (Dura-Dry, Milan, Italy) was used on 18 g of both raw and blanched (as above) basil leaves. The operative conditions were vacuum = 30 Pa, temperature range from −35 to +20 °C. The times process were 72 and 48 h for raw (RFD) and blanched (BFD) leaves, respectively, to attain final dry matter of 91.76% ± 1.78 (RFD) and 95.25% ± 2.1 (BFD). Each drying trial was repeated twice.

Volatile Compounds Analysis. Four samples of raw and dried basil were submitted to the extraction/concentration of the aroma compounds by a coupled microwave technique resin, and the essential oil obtained was analyzed by gas chromatography/mass spectrometry−selected-ion-monitoring (GC/MS−SIM) according to Di Cesare et al. (*24*). Each sample was dispersed in 300−400 mL of distilled water in a 1 L glass container equipped with two small tubes: one connected to a N_2 cylinder, the other to a glass column packed with 25 mL of KS112 apolar resin. The container was placed in a microwave oven operating at 440 W for 40 min. The volatile compounds extracted were continuouly removed from the container by an N_2 flux and adsorbed onto the resin. The aroma compounds were eluted from the resin with 100 mL of pure ethyl ether, that was then dehydrated with anhydrous Na_2S0_4 and finally removed in a Kuderna−Danish evaporator to recover the pure essential oil. For the qualitative analysis, 0.3 μL of the essential oil was injected at 200 °C into a DB-1 capillary column (60m × 0.25 mm i.d., 0.25 μm film thickness, J&W Scientific, Folsom, CA). The column temperature was kept at 50 °C for 5 min and then raised to 240 °C at a 2 °C/min heating rate; finally, it was kept at 240 °C for 20 min. The inlet flow and the split of the carrier (He) were set at 2 mL/min and 50 mL/min, respectively. The temperature of the transfer-line was 240 °C. The MS spectra were generated at 70 eV, and the 10−400 Amu mass range was selected for mean square displacement (MSD). Compounds were identified by comparing spectra of standards and spectra contained in the instrument library, or by comparing retention times of standards. Quantitative analyses, four replications for each drying trial, were carried out by SIM. Solutions of standard compounds (eucalyptol, linalool, eugenol, and methyleugenol) were prepared in ethyl ether, so as to encompass two series of concentrations. The solution was stirred for 1 h at room temperature, and the volatile compound was analyzed with the procedures described above. The characteristic ions selected for SIM analysis had masses of 81.154; 71.93; 77.164, and 91.178. The quantitative values were calculated using response factors generated with standard curves. Calibration factors were obtained by plotting the selective ion counts versus the concentrations of each volatile compounds. The recovery yield was evaluated with extraction/concentration experiments performed on dearomatized basil leaves artificially loaded with known amounts of pure standard compounds, (eucalyptol, linalool, eugenol, and methyleugenol). The tests were repeated twice.

Pigments Analysis. Chlorophyll a and chlorophyll b were determined according to Forni et al. (*25*), with some modifications. Four samples of raw (5 g) or dried (1−2 g) basil leaves were repeatedly extracted with aliquots of 20 mL acetone added with Na_2CO_3 (final pH 7) until the residue of centrifugation was decolorized. The pooled extracts (final volume 50 mL) were analyzed by HPLC on an RP18 column (Merck) with isocratic elution by acetone/ethanol/water (70/17/13), coupled with a spectrofluorimetric detector (Jasco FP110), excitation $\lambda = 413$ nm, emission $\lambda = 669$ nm, and a Shimadzu CR1A Chromatopack Data Processor. Calibration was made with chlorophyll a and chlorophyll b standard solution (Fluka). Reported data are the means of four replications and are expressed as percentage on dry weight.

Color Measurements. A Minolta Chroma Meter CR 2000 was used. Reported data were the means of six determinations. From the L^*, a^*, b^* values, the color attribute of tint angle (arctg b^*/a^*), saturation ($\sqrt{(a^{*2} + b^{*2})}$) and color difference ΔE ($\sqrt{(L^*_R - L^*_D)^2 + (a^*_R - a^*_D)^2}$

Table 2. Percent Composition of the Volatile Compounds of Raw Basil *O. basilicum* L. Leaves, Extracted by Microwave–Resin Procedure and Analyzed by GC/MS

peak[a]	compds	compsn % ± SD	peak	compds	compsn % ± SD
1	hexanal	0.29 ± 0.02	12	1,3,6-octatriene-3,7-dimethyl (Z)	1.76 ± 0.05
2	2-hexenal (E)	0.89 ± 0.04	13	sabinene hydrate (E)	0.36 ± 0.02
3	3-hexen-1-ol (Z)	0.62 ± 0.02	14	cyclohexene-1-methyl-4-(1-methylethylidene)	0.50 ± 0.02
4	1-hexanol	0.87 ± 0.07	15	linalool	7.18 ± 0.07
5	α-pinene	0.35 ± 0.01	16	camphor	0.89 ± 0.03
6	camphene	0.15 ± 0.02	17	terpinen-4-ol	0.22 ± 0.02
7	β-phellandrene	0.75 ± 0.02	18	α-terpineol	1.34 ± 0.04
8	β-pinene	0.94 ± 0.03	19	bornyl acetate	0.50 ± 0.02
9	β-myrcene	0.52 ± 0.01	20	eugenol	33.72 ± 2.13
10	eucalyptol	10.39 ± 0.05	21	methyleugenol	24.38 ± 1.42
11	β-sabinene (E)	0.16 ± 0.01			

[a] The peak numbers correspond to the numbers in **Figure 1**.

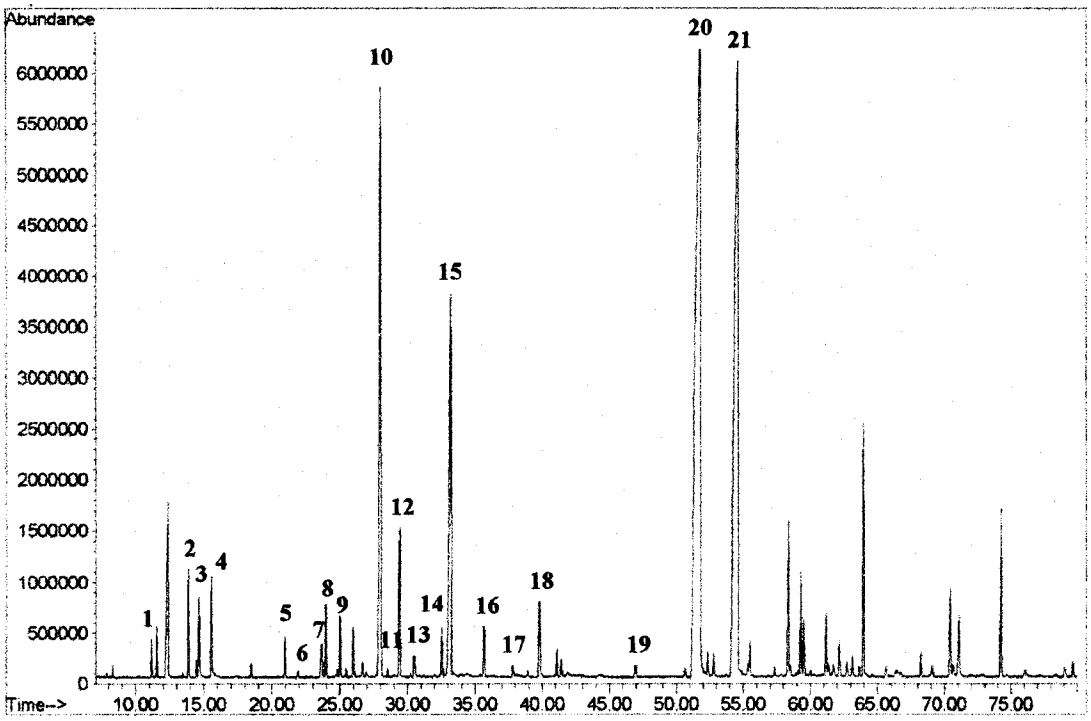

Figure 1. Typical chromatogram of volatile compounds extracted from Italian raw basil *O. basilicum* L. leaves by direct injection in GC/MS. The peak numbers correspond to the numbers in **Table 2**.

$+ (b^*_R - b^*_D)^2$) between raw (R) and dried basil leaves (D) were calculated (*26*).

Dry Matter. Dry matter of raw and dried basil was determined by using a laboratory oven kept at 103 °C. Four samples of raw or dried basil were dehydrated to a constant weight, and the moisture content was calculated from the difference between the wet and dry weight divided by the wet weight (*27*). Reported data are the means of four replications

Microscopic Analysis. Raw and dried basil leaves were immersed in a fixative medium (3% glutaraldehyde in pH 6.9 phosphate buffer), dehydrated in ethanol, cut, and stained with 0.7% rutenium red acqueous solutions or 1% toluidine blue in 0.5% acqueous sodium carbonate solution. The samples were examined with an optical microscope Leitz Dialux 20EB. Photographs of the samples were examined with a suitable software.

Statistical Analysis. the Tukey test was used to evaluate the differences between the drying treatments. Mean values were considered significantly different when $p < 0.05$.

RESULTS AND DISCUSSION

The GC/MS aroma profile reveals that the main volatile compounds from raw basil leaves were those expected from the mediterranean cultivar, particularly for the Italian basil, such as linalool, eucalyptol, camphor, eugenol, and methyleugenol. **Table 2** shows the overall GC/MS aroma profile from raw basil leaves, extracted by microwave-resin processing; eugenol was identified as the major compound (33.72%), followed by methyleugenol (24.38%), eucalyptol (10.39%), and linalool (7.18%). Other monoterpenes, oxygenated terpenes, aldehydes, and alcohols were also revealed. A typical chromatogram of flavor volatiles of raw basil leaves is shown in **Figure 1**. To quantitatively evaluate the effects of the various drying methods on the retention of volatile compounds, this work was addressed to asses the retention of methyleugenol, eugenol, linalool, and eucalyptol, wich are the character-impact compounds of basil (*22*) and constitute about 76% of the total volatiles of the herbs. **Table 3** reports the percentage retentions of the four characteristic volatile compounds of basil aroma after microwave-drying, air-drying, and freeze-drying, calculated with respect to the raw basil leaves contents. Retention of eugenol and methyleugenol between 35 and 42% and between 19 and 28% was found in the microwave-dried samples A, B, C, and D, E,

Table 3. Percentage Retention of the Characteristic Volatile Compounds of Basil (*O. basilicum* L) Dried with Different Procedures

	methyleugenol	eugenol	linalool	eucalyptol
A[a]	35.92 cde	40.94 cd	42.17 bc	29.24 ab
B	41.78 de	38.93 cd	40.72 bc	26.18 ab
C	35.60 cde	38.37 cd	58.81 c	36.76 ab
D	21.00 b	20.40 b	26.18 ab	33.16 ab
E	23.60 bc	19.60 ab	18.10 ab	13.43 a
F	28.13 bcd	24.17 bc	17.24 ab	9.13 a
R50	23.36 bc	14.52 ab	44.85 bc	44.36 b
B50	3.27a	1.56 a	3.35 a	13.18 a
RFD	45.91 e	49.32 d	62.32 c	42.06 b
BFD	22.43 bc	18.27 ab	19.06 ab	25.95 ab

[a] A, B, C, D, E, microwave-drying at different time and power as reported in **Table 1**; R50,B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively. Different letters indicate a significant difference ($p \leq 0.05$).

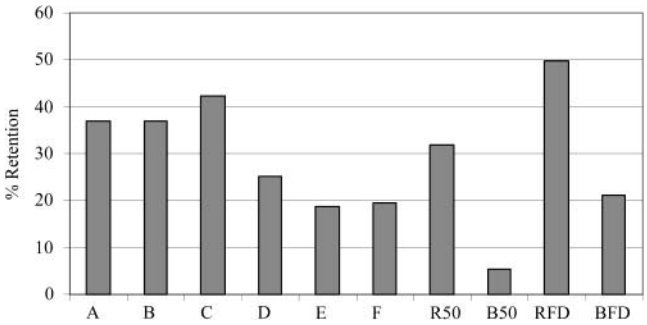

Figure 2. Percent mean retentions of some characteristic volatile compounds of the basil *O. basilicum* L. leaves aroma (linalool, eucalyptol, eugenol, and methyleugenol) after drying. (A, B, C, D, and E microwave-drying tests at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively,). Different letters indicate a significant difference ($p < 0.05$).

F, respectively. The retention of linalool in the microwave-dried sample C (59%) was lower than that in the other microwave-dried samples (40−42% for A and B; 18−26% for D, E, and F). The retention of eucalyptol was 33−36% in the microwave-dried samples C and D, while it was lower (26−29% for A and B and 9−13% for E and F) in the other microwave-dried samples.

Figure 2 shows the effects of the drying methods on the total volatile compounds contents. The values reported were calculated as one-fourth of the summed retentions of eucalyptol, linalool, eugenol, and methyleugenol. The highest mean retention (42%) was found for microwave-dried sample C, followed by A and B (36−37%), while values below 20% were obtained for the other samples.

It is known that microwaves have a high capacity to interact with water molecules, which are excited and can be quickly evaporated from the vegetable tissues. In the case of basil, if the microwave power is gradually increased, the evaporation of water is less tumultuous, and consequently, the loss of aroma compounds is lower. In every microwave test of our research (**Table 1**), the first two steps (25 and 40% power) gradually heated the basil moisture up to 100 °C, providing water vaporization and destruction of the enzymes (blanching). In test C, a third step at 60% of maximum power, before the final step of 100%, resulted in the best recovery of the volatile compounds. Larger losses aroma compounds were instead observed in the microwave tests, implying a third step at 80% (D, F) or at 100% (A, B) of maximum power, as well as in the test E with a fourth

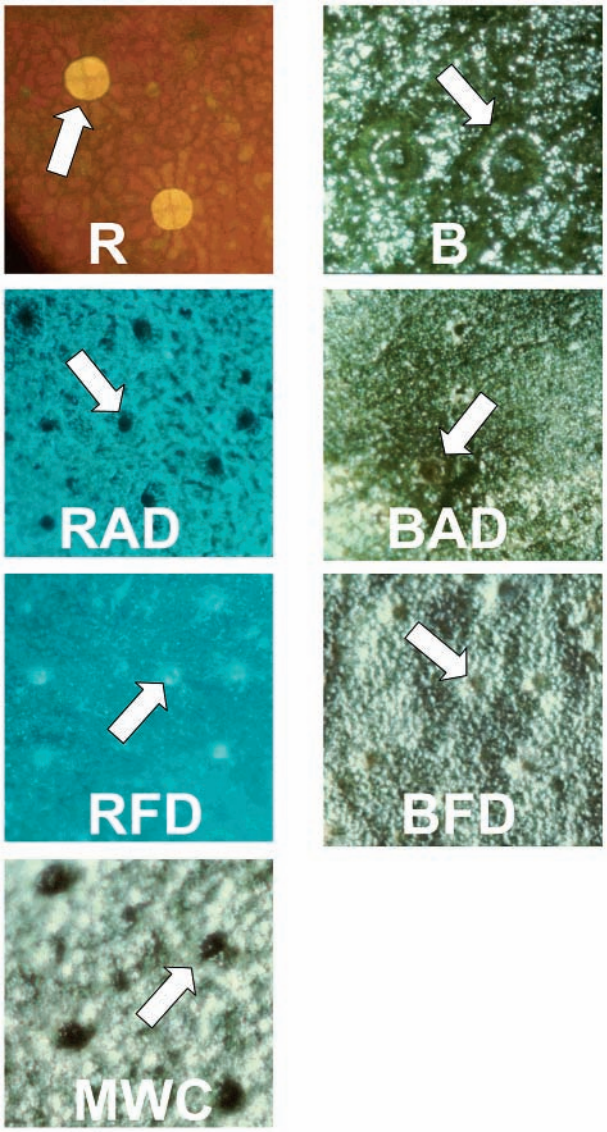

Figure 3. Effects of drying techniques on the oil glands in the epidermis of basil *O. basilicum* L. leaves. (C, microwave-drying test at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively).

step at 80% power. Lower retentions of methyleugenol, eugenol, linalool, and eucalyptol were observed in basil leaves dried by traditional methods (**Table 3** and **Figure 2**), namely air-drying and air- and freeze- drying after blanching. The only exceptions were the freeze-dried raw leaves.

As reported above, blanching and drying treatments can affect the content of the volatile compounds in dried basil leaves. The retentions of these substances depend on the integrity of the oil glands that are composed of four cells, **Figure 3R**, with a diameter of about 80 μm. The microscope examinations of the epidermis of the treated leaves revealed that the oil glands were broken after either blanching (**Figure 3B**) or drying (**Figure 3 RAD, BAD, RFD, BFD, MWC**), leaving empty holes in the glands sites. Because of this loss of integrity, the volatile compounds of essential oils can be easily removed during treatments. In the blanched leaves dried by traditional methods, the retention of the volatile compounds was very poor because of the above negative effects produced both in the blanching and in the drying step. Retention of the aroma compounds was higher in the unblanched leaves dried by the two traditional

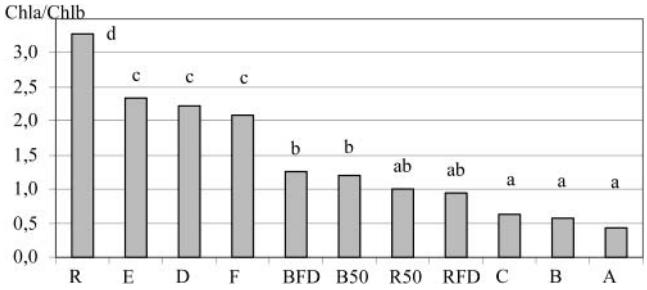

Figure 4. Chl a/Chl b ratio of basil *O. basilicum* L. leaves: R, raw;. (A, B, C, D, E, microwave-drying tests at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively). Different letters indicate a significant difference ($p < 0.05$), small letters refer to chlophyll a and capital to chlorophyll b.

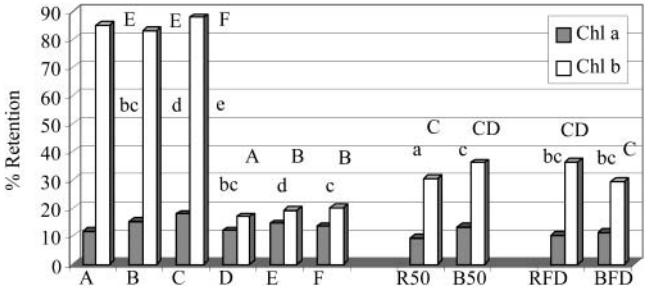

Figure 5. Percentage of residual chlorophyll a and chlorophyll b of dried basil *O. basilicum* L., with respect to the raw basil content. (A, B, C, D, E, microwave-drying tests at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively). Different letters indicate a significant difference ($p < 0.05$).

techniques, because the breakage of the oil glands took place only during the drying process. The milder operative conditions required for freeze-drying produced minor damages of the oil glands and, consequently, a better retention of the volatile substances. The retentions of the volatile compounds in microwave-dried raw leaves was almost the same as in unblanched freeze-dried basil leaves, despite the complete destruction of the oil glands. This finding could be related to the short treatment time.

Figure 4 reports the chlorophyll a/chlorophyll b ratio (Chl a/Chl b) of raw and dried basil leaves. The determination of the pigments ratio could indicate the extent of color damage in food during processing. Chlorophyll a is less stable than chlorophyll b, resulting in a faster rate of degradation (*28*). It follows that Chl a/Chl b ratio, which is about 2.5−3 in plants, will decrease in a product which is heat damaged. In microwave-dried basil D, E, F, **Figure 4**, the Chl a/Chl b ratio was slightly lower than in the raw basil. Heat damage was more evident in the case of air-drying where samples showed a larger decrease of Chl a/Chl b ratio with respect to D, E, F samples. According to literature data (*20*), basil leaves blanched before air-drying showed Chl a/Chl b ratios slightly higher than the untreated samples and a similar trend was shown comparing blanched and unblanched freeze-dried samples. This finding suggests that the protective effect of blanching on chlorophyll was primarily related to chlorophyll a. The retention of chlorophyll a and chlorophyll b, expressed as percentage of the residual pigment in dried with respect to raw basil leaves (**Figure 5**), confirmed these observations on air- and freeze-dried samples. A different behavior was observed in the case of microwave-dried basil leaves (samples A, B, and C). The Chl a/Chl b ratio decreased

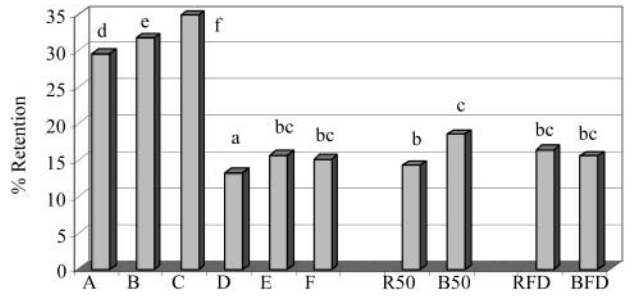

Figure 6. Percentage of residual total chlorophyll of dried basil O. basilicum L. leaves with respect to the raw content. (A, B, C, D, E, microwave-drying at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively). Different letters indicate a significant difference ($p < 0.05$).

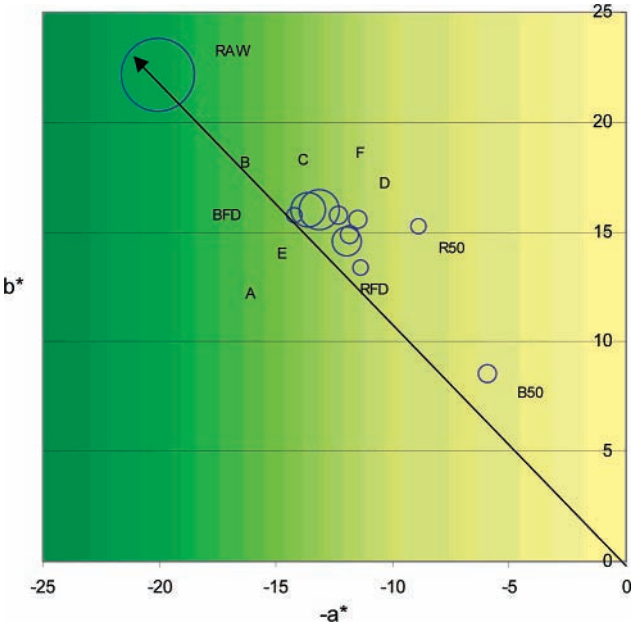

Figure 7. Location of the color of raw and dried basil *O. basilicum* L. leaves color in the $-a^*$, $+b^*$ chromatic plane. (A, B, C, D, E, microwave-drying at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively).

more than in the D, E, and F samples, because of the very high recovery of chlorophyll b (**Figure 5**). Regarding total chlorophyll pigments retention, reported in **Figure 6**, the most suitable drying treatments for basil leaves seemed to be the microwave tests A, B, and C.

Chlorophyll changes, as discussed above, were confirmed by color data. In **Figure 7**, the chromatic plane $-a^*$, b^* is reported; the greater the dimension of the circles, the higher the total cholophyll content. The arrow indicates the tint angle of the raw basil leaves. When compared to raw basil, all dried samples showed decreases in saturation (distance from the origin in the color plane), but both microwave and freeze-dried basil leaves showed a smaller decrease. Air-dried basil, with or without blanching, presented the highest heat damage. The representative point of air-dried basil is placed at the right of the hue arrow of the raw basil, in the domain of yellow-green, whereas the blanched air-dried basil, even if it is near the tint angle of the raw basil, presented the lowest value of the saturation index. Microwave-dried samples were greener in color than air-dried samples (smaller a^* values). A similar effect on color during vacuum-microwave and air-drying was also found in basil (*22*),

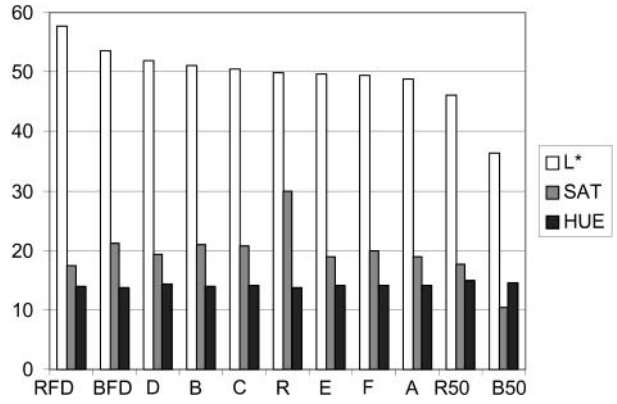

Figure 8. Lightness, (*L**), saturation, (SAT) and tint angle ((Arctg *b**/*a**)/100, HUE) of raw and dried basil *O. basilicum* L. leaves; samples are arranged according *L** decreasing. (A, B, C, D, E, microwave-drying at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively).

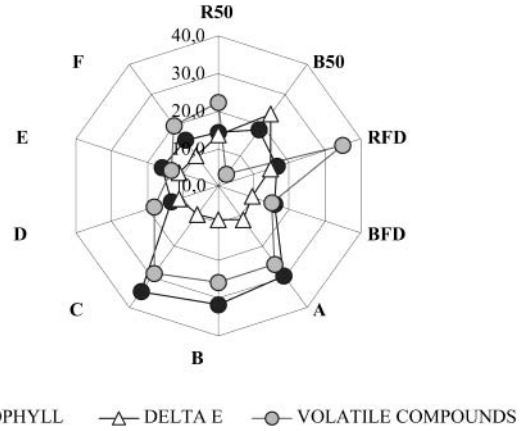

Figure 9. Comparative view of retention percentage of total chlorophyll and total volatile compounds and Δ*E* of dried basil *O. basilicum* L. leaves. (A, B, C, D, E, microwave-drying at the different time and power reported in **Table 1**; R50, B50, air-drying without or with blanching, respectively; RFD, BFD, freeze-drying without or with blanching, respectively).

and in carrot chips (*29*), the latter being darker and with less red and yellow hue than vacuum-microwave-dried ones. In **Figure 8** the color data of *L**, lightness, saturation (SAT) and tint angle (HUE) of raw and dried basil are reported. Samples are arranged according to decreasing *L** values. Raw basil is in the middle of the diagram, and the opposite effects of the different drying techniques on these parameters are evident; the highest lightness values were obtained for freeze-dried samples either blanched or not, while air-drying gave the darkest products, especially after blanching. All microwave-dried basil leaves were very similar to the raw ones for this attribute. These results agree with the already observed high *L** values for microwave-dried oregano (*30*): the authors reported that, during the shorter drying period of the vacuum-microwave treatment, compared to air-drying, less browning was observed. During the slow and long-lasting air-drying, the heat went from the surface to the interior of the product so that the rate of water evaporation on the surface was faster than the diffusion to the surface. Moreover, heat and atmospheric oxygen facilitated a high enzymatic activity of polyphenol oxidase, causing a browning effect. Less browning (higher *L** values) was observed during the short period of drying in a vacuum-microwave for basil leaves (*22*) or in microwave-blanching compared with water-blanching for spinach (*31*). Microwave-dried basil leaves also showed a lower decreases of saturation (**Figure 8**) than air-dried or freeze-dried ones. According to Rocha (*20*), the lower value of saturation was obtained for air-dried basil leaves. As already shown in **Figure 7**, the only tint angle modification was revealed in the air-dried samples. Close relationships between the saturation values and total chlorophyll contents were obtained with $R^2 = 93\%$ in the case of microwave-dried basil leaves.

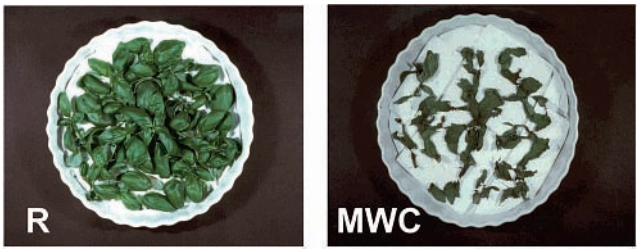

Figure 10. Raw (R) and microwave-dried (C) basil *O. basilicum* L. leaves.

This research shows a possible use of microwave to dry basil leaves, as an alternative technique. Microwave dried basil leaves show a larger retention of both volatile compounds and chlorophyllic pigments when compared to the leaves dried by traditional techniques. Our results are summarized in **Figure 9**. Microwave drying gave the best retention of both aroma compounds and chlorophylls and the lowest values of Δ*E* (color difference calculated between raw and dried basil leaves), followed by freeze-drying. Moreover, microwave-drying requires a shorter process with respect to traditional methods, and implies simultaneous blanching and drying trearments. This reduces the loss of salts, acids, volatile compounds, and chlorophylls, whereas this undesiderable phenomena commonly occurs when the blanching in boiling water precedes traditional drying.

Basil (*O. basilicum* L.) leaves before and after microwave-drying are shown in **Figure 10**.

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