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Effect of Blanching on the Quality of Microwave Vacuum Dried Dill (*Anethum graveolens* L.)

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***Abstract*—**Dill (*Anethum graveolens L.*) is a popular herb used in many regions, including Baltic countries. Dill is widely used for flavoring foods and beverages due to its pleasant spicy aroma. The aim of this work was to determine the best blanching method for processing of dill prior to microwave vacuum drying based on sensory properties, color and volatile compounds in dried product. Two blanching mediums were used – water and steam, and for part of samples microwave pretreatment was additionally used. Evaluation of dried dill volatile aroma compounds, color changes and sensory attributes was performed. Results showed that blanching significantly influences the quality of dried dill. After evaluation of volatile aroma compounds, color and sensory properties of microwave vacuum dried dill, as the best method for dill pretreatment was established blanching at 90 °C for 30 s.

***Keywords*—**dried dill, sensory panel, sensory properties, aroma compounds, color

I. Introduction

DILL, peppermint and basil are traditionally grown cash crops in Europe and Central Asia for the production of fresh herbage, dry leaves or essential oils [1], [2]. The products from these plants find their applications as culinary herb (dill, oregano, rosemary, thyme, parsley, spring onions, garlic, etc.) or as minor adjuncts to salads (fresh herbs) and herbal teas (dry leaves/ shoots) and as aromatic agents in the food, pharmaceutical, perfumery and cosmetic, functional food and nutraceuticals industries [2]–[4].

Dill (*Anethum graveolens L.*), a biennial or annual herb of the parsley family (*Apaceae* or *Umbelliferae*), is popular herb widely used in many regions, including Baltic countries. Cultivated since antiquity, dill is a hardy annual or biennial plant and has a single stem with a terminal or primary umbellate flower [5]. Use of fresh herbs is limited due to the seasonality, therefore it is necessary to find best solution for processing, and the most popular methods are drying and freezing. Drying is one of the oldest methods of food preservation and represents a very important aspect of food and herbs processing [6]. The drying method is an important factor affecting the quality of dried product, and the most popular methods are air drying. Recently popularity of microwave vacuum and freeze drying has considerably increased.

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As a preservation process, blanching has a number of advantages including, excellent color stability, an improvement in texture, a decrease in viable counts, and the elimination of undesirable substances [7]. The quality of blanched product depends significantly on the time and temperature of blanching and also on the size of product to be blanched. Under-blanching speeds up the activity of enzymes and is worse than no blanching. Over-blanching causes loss of texture, color, phytochemicals and minerals [8]. One of the important quality attributes of herbs that changes during processing steps is aroma and in the current study aroma compounds were analyzed both by GC and also by sensory evaluation. The aroma composition of dill before fruit formation is due to phellandrene and dill ether (3,9-epoxy-1-*p*-menthene). The odor of phellandrene is described as “dill-like, fragrant, fresh,” while carvone, characteristic of seed oil, is “caraway-like, cooling” and dill ether is “dill-like, floral, fragrant” [9]. Limonene and α-pinene also contribute to oil aroma with “citrus-like, fresh” and “pine-like” odors, respectively. Carvone is synthesized from phellandrene during the day [10], and according to research cited in reference [11] from limonene as well. Besides differences in chemical compounds forming aroma, their sensory properties are important.

Sensory evaluation – a scientific discipline used to evoke measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory evaluation involves the interpretation of the responses by the sensory professional [12]–[14]. Sensory properties are some of the most important factors on consumer liking and preference; thus it is very important to determine factors affecting the product attributes, acceptance and preference especially for foods [15], [16]. The studies on influence of drying process on nutritional and sensory quality such as flavour, aroma and color of dill leaves is limited [6].

One of the most important sensory traits is the color [17], which depends on dill variety, growing conditions, processing technology and storage conditions. The aim of this work was to determine the best blanching method for processing of dill prior to microwave vacuum drying based on sensory properties, color and volatile compounds in dried product.

II. Material and Methods

Experiments were carried out at the Faculty of Food Technology, Latvia University of Agriculture in 2011.

A. Raw materials

Dill variety ‘Superdukat’ was grown in the test fields of the Latvia University of Agriculture and harvested at the height of

30–35 cm. After harvest dill was washed and separated in two fractions: leaves and stems. For further analyses dill leaves were used.

B Pretreatment process

Blanching in water, steam, and combined treatment of microwave and water or microwave and steam was applied to dill prior to drying.

Dill leaves were water blanched at:

- 90 °C temperature for 30 s;
- 70 °C temperature for 60 s.

Dill was treated in steam at 95±1 ºC for 30 s.

For microwave (MW) pretreatment dill leaves were positioned on the plates (20-cm diameter) and placed on the turntable plate of the microwave variable power oven (model EMS 28405, Electrolux, Sweden). Power level of 900 W was used for 30 s treatment. After microwave pretreatment dill was subjected to blanching in hot water or steam. Dill immediately after blanching was cooled in tap water. All treatments were carried out in triplicate.

C Drying

After blanching dill leaves were cut in slices 0.4±0.1 cm and dried using a microwave-vacuum drier „Musson-1" (OOO „Ingredient", St. Petersburg, Russia). Characteristic parameters of drying program were as follows:

- number of magnetrons was decreased along the drying process (starting at 4, and then followed by 3, and finally 2);
- pressure 12.00-14.63 kPa;
- drum rotation speed – 6 rpm;
- product mass per load – 1 kg;
- drying time – 17 min.

The following abbreviations of the samples in article are used:

Sample A – fresh dill;

Sample B – unblanched dill;

Sample C – water blanched dill at 70 °C for 60 s;

Sample D – water blanched dill at 70 °C for 60 s, pretreated using microwaves;

Sample E – water blanched dill at 90 °C for 30 s;

Sample F – 90 °C for 30 s, pretreated using microwaves;

Sample G – steam blanched dill;

Sample H – steam blanched dill, pretreated using microwaves.

D. Detection and identification of volatile aroma compounds

Volatiles from dried dill were extracted using solid phase microextraction (SPME). 0.5 g of sample were weighed in a 20 ml headspace vial and capped with a septum. For SPME extraction a divinylbenzene/Carboxen/ polydimethylsiloxane (DVB/Car/PDMS) fiber (Supelco Inc., Bellefonte, PA, USA) was used. SPME parameters were: incubation time 10 min, extraction temperature 35±1 °C, extraction duration 10 min, desorption 15 min at 250 °C. For the analysis of the SPME extracts, a *Perkin Elmer Clarus 500 GC/MS* and an Elite-Wax ETR column (60 m x 0.25 mm i.d.; DF 0.25 μm) was used. Working conditions were: injector 250 °C; transfer line to MSD 260 °C; oven temperature start 40 °C, hold 10 min, programmed from 40 to 60 °C at 2 °C min^{-1}, and from 60 to 250 °C at 20 °C min^{-1}, hold 5 min; carrier gas (He) 1 ml min^{-1}; split ratio 2:1; ionization EI+ mode; acquisition parameters in full scan mode: scanned m/z 40–400.

Compounds were identified by comparison of their mass spectra with mass spectral libraries (Nist98), and by calculation of linear retention indexes and comparison with literature data. All analyses were performed in triplicate. Compounds in the tables are shown in the order of the retention time. As a quantitative measure, the share in the total GC peak area for each compound is given.

A coefficient K was calculated using the least-squares method to compare the relative amounts of volatiles in dried dill leaves versus fresh dill leaves.

$$K=(A_h-A_o)^2+(B_h-B_o)^2+(C_h-C_o)^2+.....+(X_h-X_o)^2 \quad (1)$$

where

A_h, B_h, C_h, ..., X_h – percentage of volatile compounds A, B etc. in the headspace of fresh dill leaves,

A_0, B_0, C_0, X_0 – percentage of volatile compounds A, B, C etc. in the headspace of dried dill.

Thus, the smaller the coefficient K, the greater the similarity of dried dill aroma to fresh dill leaves aroma.

E. Instrumental color analysis

Color of dried dill was measured in CIE L*a*b* color system using a *ColorTec-PCM/PSM* (Accuracy Microsensors Inc., USA). Before measuring, the colorimeter was calibrated using a white reference tile and a light trap (black tile). Ten random areas were measured through the plastic pockets and mean values were reported for each sample. In color measurement, CIELAB coordinates show the degree of brightness (L), the degree of redness (+a), or greenness (–a), and the degree of yellowness (+b), or blueness (–b), respectively. An important factor characterizing the variation of color in the test sample is total color difference (ΔE) or TCD [18], [19]. The total color difference (ΔE) was defined by the Minolta equation (2):

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

where

$\Delta L=L-L_0$, $\Delta a=a-a_0$, $\Delta b=b-b_0$,

L, a, and b are the measured values of dried samples,

L_0, a_0, and b_0 are the original values of fresh dill.

F. Sensory analysis

The panelists were selected and trained according to the recommendations described in ISO 8586-1 (1993) [20]. Forty five applications (9 men and 36 women) from the public and PhD students of Faculty of Food Technology were received for training. Training was completed at the Latvia University of

Agriculture. It was done in two sessions – training and selection of panelists, and specific training for evaluation of dill sensory properties.

References were determined by consensus of all 10 selected assessors (2 men and 8 women). The assessors were further trained on the product attributes using identified references. The following dill attributes were analyzed for fresh dill: appearance, aroma, color, taste and dill stem; and for dried dill – appearance, aroma and color.

1. Selection of assessors

Scheme for training of the panelists/assessors is presented in Fig. 1.

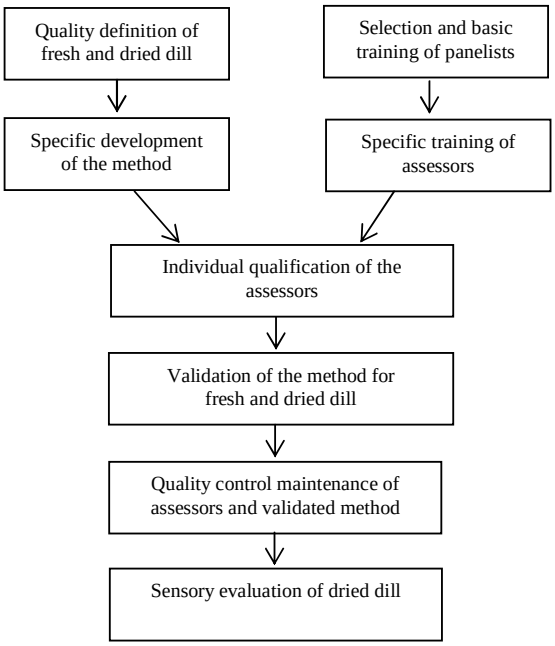

Fig. 1 Scheme for training of panelists for dill sensory evaluation

2. Evaluation of the dill quality

For evaluation of dill sensory properties was used quality number (QN), calculated according to the following equation [21]:

$$QN = \frac{Ap + Co + Ar}{3} \quad (3)$$

where
Ap – dried dill appearance,
Co – dried dill color,
Ar – dried dill aroma.

Based on QN dried dill quality was classified as follows:

7.00–6.50 –very good quality (performance of quality parameters);

6.49–5.50 – good quality (inessential deviations);

5.49–4.00 – average quality (pronounced deviations, insignificants defects);

3.99–2.90 –satisfactory quality (significant defects);

2.89–1.00 – unsatisfactory quality (serious defects).

3. Sample preparation for sensory evaluation

Fresh dill, commercial dried dill samples from local market and dried dill samples obtained in experiments were evaluated in the study. For each panelist 50 g of fresh dill and 10 g of dried dill were provided.

G.Statistical analysis

The results were processed by mathematical and statistical methods. Data were subjected to one way analysis of variance (ANOVA) and two way analysis of variance (ANOVA), by Microsoft Office Excel 2007, significance was defined at $p < 0.05$.

III. RESULTS AND DISCUSSION

A. Volatile aroma compounds

The main aroma compounds of fresh dill leaves are α-phellandrene and dill ether (Table 1) and these results are comparable with those found in literature [22], [23]. Both mentioned compounds α-phellandrene and dill ether gives typical dill flavor [24]. The percentage of dill ether in headspace of dried samples is significantly lower (0.97–7.31%) than in fresh dill (31.61%).

TABLE I
DILL HEADSPACE AROMA COMPOSITION

Samples	Volatile compounds						K
	α-pinene	α-phellandrene	Limonene	β-phellandrene	Cymene	Dill ether	
A	2.15 ± 0.06	42.93 ± 1.23	4.91 ± 0.14	9.85 ± 0.28	2.58 ± 0.07	31.61 ± 0.9	-
B	1.8 ± 0.04	61.4 ± 1.43	5.64 ± 0.13	13.65 ± 0.39	14.92 ± 0.43	1.16 ± 0.03	1436
C	2.24 ± 0.06	68.8 ± 1.6	4.27 ± 0.1	12.19 ± 0.35	10.32 ± 0.29	0.97 ± 0.03	1674
D	2.72 ± 0.08	67.08 ± 1.56	3.53 ± 0.1	9.79 ± 0.28	8.68 ± 0.25	6.68 ± 0.19	1244
E	1.36 ± 0.04	72.98 ± 1.7	3.3 ± 0.08	8.5 ± 0.2	5.56 ± 0.16	7.31 ± 0.21	1507
F	2.43 ± 0.07	63.69 ± 1.82	6.81 ± 0.19	15.14 ± 0.48	7.78 ± 0.22	1.25 ± 0.04	1412
G	1.66 ± 0.05	71.91 ± 2.05	4.32 ± 0.12	11.97 ± 0.38	4.06 ± 0.12	4.54 ± 0.13	1580
H	2.6 ± 0.08	64.87 ± 2.05	5.75 ± 0.18	14.03 ± 0.44	7.53 ± 0.24	3.35 ± 0.11	1323

Fresh and dried dill contained β-phellandrene that gives minty aroma [25]. Limonene in dill ranged between 3.30–6.81% and its aroma in literature is described as lemon and mint [26].

The highest total peak area of identified aroma compounds of dried dill was established in the samples pretreated with microwaves and blanched at 90 ºC for 30 s (Fig. 2).

The composition of volatile compounds of dried dill is affected by the conditions of blanching, so it is important to determine which method results in dried dill having a composition more similar to that of fresh dill leaves and stems.

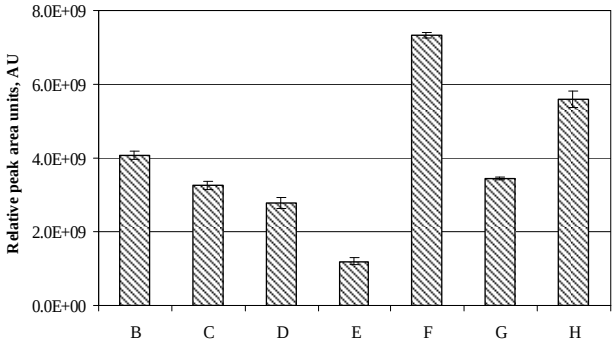

Fig. 2 Total relative peak area of identified compounds

A – fresh dill; B – unblanched dill; C – water blanched dill at 70 °C temperature 60 s; D – water blanched dill at 70 °C temperature 60 s pretreated with microwaves; E – water blanched dill at 90 °C temperature 30 s; F – 90 °C temperature 30 s pretreated with microwaves; G – steam blanched dill; H – steam blanched dill pretreated with microwaves.

Deviation square sum was calculated to compare the percentage composition of fresh and dried dill (Table 1).

If the volatile compound composition by percentage for fresh and dried dill is the same, then deviation square sum is 0. Thus, the smaller the coefficient, the greater similarity exists between the fresh dill aroma and the dried herb aroma. The content of volatile compounds of dried dill pretreated with microwaves and blanched at 70 ºC for 60 s is the most similar to the composition of fresh dill leaves, whereas the least similar is the samples blanched at 70 ºC for 60 s without microwave pretreatment.

B. Color analysis

Effect of blanching on dill color change is evaluated using CIE L*a*b* color system, and the obtained results are presented in Table 2.

Analysis of the results show, that blanching method does not have significant effect ($p > 0.05$) on color component L* (degree of brightness). The sample A (fresh dill) was used as a control for calculation of color difference. Color components a* and b* of the sample B (unblanched dried dill) were the most similar to fresh dill.

TABLE II
COLOR VALUES OF DRIED DILL

Samples	Color values		
	L*	a*	b*
A	37.78±1.82	-4.21±0.12	14.96±0.45
B	39.24±1.19	-2.89±0.06	13.87±0.42
C	33.64±2.20	-2.15±0.05	8.14±0.16
D	35.23±1.89	-0.24±0.01	6.43±0.13
E	34.95±1.90	1.15±0.06	8.59±0.34
F	34.27±1.61	-0.81±0.04	10.04±0.10
G	37.41±2.19	-0.94±0.04	11.59±0.46
H	34.40±1.40	1.05±0.03	8.91±0.18

A – fresh dill; B – unblanched dill; C – water blanched dill at 70 °C temperature 60 s; D – water blanched dill at 70 °C temperature 60 s pretreated with microwaves; E – water blanched dill at 90 °C temperature 30 s; F – 90 °C temperature 30 s pretreated with microwaves; G – steam blanched dill; H – steam blanched dill pretreated with microwaves.

For calculation of the total color difference (ΔE) the equation (2) was used and the evaluation results are summarized in Fig. 3.

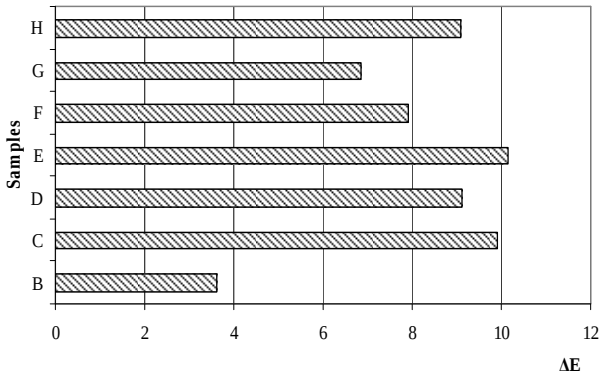

Fig. 3 The total color difference (ΔE) of dried dill, comparing to fresh dill color

A – fresh dill; B – unblanched dill; C – water blanched dill at 70 °C temperature 60 s; D – water blanched dill at 70 °C temperature 60 s pretreated with microwaves; E – water blanched dill at 90 °C temperature 30 s; F – 90 °C temperature 30 s pretreated with microwaves; G – steam blanched dill; H – steam blanched dill pretreated with microwaves.

The smallest difference in color between fresh and dried dill can be achieved when combined pretreatment of microwaves and water blanching is applied (Fig. 3). Contrary, combined pretreatment of microwaves and steam blanching increase the total color difference, comparing to sample without microwave pretreatment (Sample H and G).

Blanching method affects color of dried dill significantly ($p \leq 0.05$) (Fig. 3). The smallest total color difference ($\Delta E = 3.62$) was determined for unblanched dried dill (Sample B) allowing to draw a conclusion that this type of treatment has no significant effect on color. When water blanching at 70 °C for 60 s and water blanching at 90 °C for

30 s was used for dill pretreatment, the total color difference (ΔE) was the biggest – ΔE = 10.57 (Sample E) and ΔE = 9.91 (Sample C), which can be due to leaching of color forming substances into water used for blanching [27].

C. Sensory analysis

Authors did not find published information on sensory evaluation methods for qualitative assessment of fresh or dried dill. Therefore the panel, prior to the assessment, was trained on various samples of fresh commercial dried dill from local market and dried dill processed using various blanching methods. The assessors developed a list of attributes for the project and agreed on a list of 31 attributes (Table 3) for fresh dill and 18 attributes (Table 4) for dried dill for the profiling and the definition of each attribute.

TABLE III
LIST OF SENSORY ATTRIBUTES OF FRESH DILL WITH DESCRIPTIONS

Characteristics		Description
Appearance	Fresh	Fresh dill appearance
	Rich green, juicy	Dill is slightly wilted
	Unsightly	Dill has lost freshness
	Sere	
	Unattractive	
Color	Green	Characteristic color of fresh dill
	Typical green	
	Non typical green	Dill is light green and color is untypical for fresh dill
	Yellowish- green	
	Greenish – yellow	First signs of drying up
	Greenish grey	Dill is slightly dried up, first signs of spoilage
	Brown	Dill is stored too long and spoilage has started
Aroma	Typical fresh dill aroma	Characteristic aroma of fresh dill
	Aromatic	Pleasant dill aroma
	Untypical fresh dill aroma	Dill aroma is not noticeable
	Green	Green grass flavor
	Hay-like	Hay flavor
	Rancid	After long storage at high humidity dill spoilage has started
Taste	Spicy	
	Herbaceous	Fresh dill taste
	Dill	
	Fresh	
	Green grass	Green grass taste
	Refreshing	Refreshing essential oil taste
	Bitter	Bitter, pungent, but pleasant taste
	Menthol	
Dill stem	Fresh	Fresh dill stem appearance
	Rich green, juicy	Slightly wilted
	Unsightly	
	Sere	Dill stems have lost freshness
	Unattractive	

Fresh dill should be of rich green color, juicy, and with typical dill aroma and taste (spicy, herbaceous, dill, fresh) and stem should be firm and juicy. If dill wilting has started, its color can change to yellowish- green or greenish – yellow, aroma becomes untypical for fresh dill and/or hay-like. When dill spoilage has started, those get unattractive appearance, color – greenish grey or brown, aroma – rancid, taste – bitter, but, when dill is completely spoiled, their stems are unsightly, sere and unattractive, the taste evaluation is skipped. The fresh dill descriptors developed and approbated during the training of the sensory panel were used as a basis for description of dried dill sensory attributes (Table 4).

TABLE IV
LIST OF SENSORY ATTRIBUTES OF DRIED DILL WITH DESCRIPTIONS

Characteristics		Description
Appearance	Uniformly sliced	Dill has uniform size
	Dill can be recognized	
	Uniformly sliced	
	Unattractive	Pretreatment operations are done according to the technology
	Powdery	Dill is sliced too finely
	Agglutinated pieces	Dill stored under humid conditions
Color	Green	Characteristic color of fresh dill
	Typical green	
	Non typical green	Dill are light green and color is untypical for dill
	Yellowish- green	
	Greenish – yellow	
	Greenish grey	Inappropriate drying regime was applied, dill has been overheated
	Brown	
Aroma	Typical dill aroma	Characteristic aroma of dill
	Aromatic	Pleasant dried dill aroma
	Green	Green grass flavor
	Hay-like	Hay-like flavor
	Rancid	After long storage at high humidity dill started to spoil

In sensory evaluation of dried dill the appearance, color and aroma were analyzed. Dried dill was evaluated after processing so comparing to evaluation of fresh dill the stem description becomes impossible. It is known that various types of processing – freezing, blanching, drying – has effect on dill and other herb aroma and color [6], [17]. Dill quality can be regarded as good if those are uniformly sliced, it is possible recognize dill leaves, color is green (as much as possible close to fresh dill color) and it has typical dill aroma. If dill pieces does not have uniform size those can be described as un-uniformly sliced, unattractive (dill cannot be recognized) or powdery (dill is too finely cut or crumbled during the processing).

Passing various processing steps dill can obtain color which can be described as non typical green, yellowish- green, greenish – yellow or greenish grey. If dried dill color is brown it may indicate that inappropriate drying parameters have been used. During drying dill may lose its typical aroma, obtaining hay-like aroma, in its turn if inappropriate storage conditions are applied (increased humidity) dried dill may obtain rancid aroma.

Based on the attributes described in Tables 2 and 3, a seven point scale was developed for sensory evaluation of fresh and dried dill. The attributes having similar meaning were combined, but some attributes named during the training session were not included in the final evaluation list because the discussions proved them to be not suitable for dill evaluation. During evaluation session each assessor marked the evaluation in the scale from 1 to 7, according to the assigned term, the best describing quality of the sample. The obtained results were used for a calculation of the quality number (QN) according to the equation (3). The results of dried dill sensory evaluation are presented in Table 5.

TABLE V
SENSORY QUALITY OF DRIED DILL ASSESSED USING 7-POINT SCALE

Samples	QN	Description
90 °C temperature 30 s pretreated with microwaves	5.52	Good quality
unblanched dill	4.93	
steam blanched dill	4.89	
water blanched dill at 90 °C temperature 30 s	4.52	Average quality
steam blanched dill pretreated with microwaves	4.04	
water blanched dill at 70 °C temperature 60 s pretreated with microwaves	3.37	Satisfactory quality
water blanched dill at 70 °C temperature 60 s	2.78	Unsatisfactory quality

Sample F (blanched at 90 °C for 30 s, pretreated with microwaves) received the highest quality number 5.52. In the sample the lumps were present, therefore the color was typical green, but slightly uneven. Aroma of the sample did not depend on blanching and drying parameters, it was typical dill aroma. The samples B (unblanched dill), G (steam blanched), E (water blanched dill at 90 °C for 30 s), and H (steam blanched dill pretreated with microwaves) was of average quality (quality number 4.04–4.93). The main deviations were found in color of the samples – grayish green (Samples B and H) to yellowish green (Sample E). The sample H was lumped and its color was gray. The sample C (water blanched dill at 70 °C for 60 s) had the lowest quality – it was lumped, its color was described as untypical for dill, grayish brown, aroma – untypical dill aroma. It allows drawing a conclusion that blanching has effect on dried dill color and aroma.

IV. CONCLUSION

1. Results showed that blanching significantly influences ($p < 0.05$) the aroma compounds, total color difference (ΔE) and sensory properties of microwave vacuum dried dill.
2. The highest total peak area of identified aroma compounds of dried dill was established in the samples pretreated with microwaves and blanched at 90 °C for 30 s. The smallest total color difference ($\Delta E=3.62$) was determined for unblanched dried dill.
3. Dried dill blanched at 90 °C for 30 s, pretreated with microwaves received the highest quality number 5.52 – the color was typical green, but slightly uneven.
4. After evaluation of volatile aroma compounds, color and sensory properties of microwave vacuum dried dill, as the best method for dill pretreatment was established combined microwave and water blanching at 90 °C for 30 s.

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