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ORIGINAL RESEARCH PAPER

HOW PROPERTIES OF EDIBLE OILS ARE IMPROVED BY ESSENTIAL OILS

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Abstract: The main aim of the present paper is to find out whether the addition of essential oils determines better oxidation stability and positive change of sensory and hedonic perception of edible oils. The oxidation stability of sunflower, corn and grape seed oils was analyzed in the presence of antioxidants in essential oils of rosemary (*Rosmarinus officinalis*), thyme (*Thymus vulgaris*) and basil (*Ocimum basilicum*) during storage, under conditions of accelerated oxidative processes (4 days, at 60 °C). The total phenolic compounds of these essential oils were determined by the Folin-Ciocalteu method. The DPPH method was used to evaluate the antioxidant capacity of basil, rosemary and thyme essential oils in comparison with known synthetic antioxidant *L(+)*-ascorbic acid. The addition of essential oils to edible oils, the amounts proposed in analyses, determines a favorable influence on their oxidation stability as well as their taste. The influence of addition of essential oils on the taste of edible oils was studied in two products consumed mainly at breakfast, bread and spinach leaves. The results recommend the use of these plant extracts as additives in edible oils rather than synthetic antioxidants.

Keywords: *DPPH method, essential oil, sensorial characterization, total polyphenol antioxidant*

INTRODUCTION

During production, refining and storage of oils, in the presence of air and light, physico-chemical and organoleptic properties are modified. Changes that occur consist in oil acidity increase, odor and a pungent taste, or both these effects [1].
Edible oils with a higher content of unsaturated fatty acids, especially polyunsaturated fatty acids are more susceptible to oxidation. Stability of various types of vegetable oils can be improved by addition of essential oils from plants used as condiments such as mint (*Mentha spicata* L.), laurel (*Laurus nobilis* L.), myrtle leaf (*Myrtus communis*) [2], thyme (*Thymus vulgaris*), rosemary (*Rosmarinus officinalis*), basil (*Ocimum basilicum*), sage (*Salvia pisidica)*, clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum zeylanicum*) and oregano (*Origanum vulgare*) [3 – 6].
This study aims firstly to evaluate the stability of sunflower, grape seed and corn oils in the presence of antioxidants (polyphenols) from thyme, basil and rosemary essential oils and the influence of their addition on the flavor of edible oils analyzed and secondly to find out how sensorial properties (taste and odor) of edible oils consumed freshly with bread (as bake rolls or bruschetta, for example) or in spinach salad dressing are influenced by the use of rosemary, basil and thyme extract oils in edible oils.

MATERIALS AND METHODS

Materials

The essential oils samples of basil (10 mL, ρ = 0.9066 g·mL^{-1}), rosemary (10 mL, ρ = 0.9172 g·mL^{-1}) and thyme (10 mL, ρ = 0.9183 g·mL^{-1}) were purchased from herbal pharmacy (Solaris plant) and edible oils, such as sunflower oil (1000 mL, ρ = 0.9163 g·mL^{-1}), grape seeds oil (250 mL, ρ = 0.9199 g·mL^{-1}), and corn oil (1000 mL, ρ = 0.9157 g·mL^{-1}) are from Romanian supermarkets.

Reagents

The reagents used to analyze total phenolic compounds consist in a mixture of phosphotungstic acid ($H_3PW_{12}O_{40}$) and phosphomolybdic acid ($H_3PMo_{12}O_{40}$), which after the oxidation of phenols is reduced to a mixture of blue oxides of tungsten (W_8O_{23}) and molybdenum (Mo_8O_{23}). The reagents used in peroxide value determination are: chloroform, glacial acetic acid, potassium iodide solution, saturated $Na_2S_2O_3$ 0.1 N solution, starch solution 1 %. All the reagents used were purchased from Sigma-Aldrich (Germany) and all were of pro analysis purity.

Methods

Having in view that oxidation of oils modifies the organoleptic properties and affects the shelf life of the product tests of accelerated oxidation at elevated temperatures are used [7]. The samples of edible oils were analyzed in normal conditions of storage and after 4 days at 60 °C in oven in conditions of accelerated oxidation, in the presence or absence of antioxidants from essential oils. All determinations were made in triplicates and the data were expressed as mean ± standard deviation.

Total phenolic contents of essential oils

The method Folin-Ciocalteu, based on power reduction of phenol hydroxyl groups, was used for spectrophotometric determination of total phenol contents. A volume of 50 µL of different essential oil was mixed with 250 µL of Folin-Ciocalteu reagent and 500 µL of sodium carbonate (20 %, w/v). The mixture was agitated and diluted with water to a final volume of 5 mL. After incubation for 30 min at room temperature, the absorbance was read at 765 nm with a UV-VIS spectrophotometer (UV-2550, Shimadzu, Japan) and total phenols in the essential oils were expressed as gallic acid equivalents (GAE), using a calibration curve (5, 10, 15, 20, 25, 30, 35, 40, 45, 50 $\mu g \cdot mL^{-1}$) of a freshly prepared gallic acid solution.

Determination of essential oils antioxidant activity with 2, 2'-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method

The antioxidant capacity of essential oils of rosemary, thyme and basil was measured in terms of hydrogen donating or radical scavenging ability, using the stable radical, DPPH [8]. The samples (from 0.01 to 50 $\mu g \cdot mL^{-1}$) were mixed with 1 mL of 0.004 % DPPH solution and filled up with 96 % ethanol, to a final volume of 4 mL. The absorbance of the resulting solutions and the blank were recorded after 1 hour at room temperature. The disappearance of DPPH was read spectrophotometrically at 518 nm using a UV-VIS-NIR spectrophotometer (UV-3600, Shimadzu, Japan). Ethanol was used to zero the spectrophotometer. Inhibition of free radical by DPPH in percent (%) was calculated by the formula:

$$I(\%) = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100 \quad (1)$$

where: A_{blank} is the absorbance of the control reaction mixture excluding the test compound and A_{sample} is the absorbance of test compound.

Determination of oil peroxide index (PV)

Peroxide value (noted PV) indicates the initial step of oxidation and it is determined using the standard analytical method, based on iodometric titration of oil sample with thiosulphate solution in the presence of starch as indicator [9, 10]. Meanwhile, a blank was prepared.

The percentage value of the peroxide index (PV) evolution (noted $r_{peroxide}$ (%) can be calculated by the formula (2), which can emphasize the percentage of final value of PV after storage ($f_{peroxide}$) comparative to initial values of PV ($i_{peroxide}$):

$$r_{peroxide}(\%) = \frac{f_{peroxide} - i_{peroxide}}{i_{peroxide}} \times 100 \quad (2)$$

Acidity oil determination

The sample dissolved in a mixture of ethanol and ethyl ether is titrated with KOH solution in the presence of phenolphthalein as indicator. The results are expressed in percentage of oleic acid.

The percentage value of the acidity evolution (noted $r_{acidity}$ (%)) can be calculated by the formula (3), which can emphasize the percentage of final value of acidity after storage ($f_{acidity}$) comparative to initial values of acidity ($i_{acidity}$):

$$r_{acidity}(\%) = \frac{f_{acidity} - i_{acidity}}{i_{acidity}} \times 100 \quad (3)$$

Sensory evaluation

Sensory attributes taste and odor are considered significant determinants of food acceptance [11]. To study these attributes, 9 samples of oils were prepared as follows: 25 mg of essential oil (basil, thyme and rosemary oil) were added in 1 kg of sunflower, grape seeds and corn oils.
The participants in consumer panel (n = 20, mean age = 21.78 years old, standard deviation = 3.53) were students of the Faculty of Food Engineering, "Stefan cel Mare" University of Suceava, Romania, of both sexes (gender: female 12 and male 8) in June 2015. The panelists were asked not to smoke, eat or drink anything (except water) for 1 hour before the tasting sessions. The samples were served in plates at room temperature and evaluated in individual booths [11]. They were given to taste one set of 9 samples of rectangular bread pieces of approximately 1 - 2 cm, containing 1 mg of each type of oils samples mentioned above, coded with different 3 digit codes, and served at room temperature in a randomized order. After 1 hour, a second set of the 9 coded samples of fresh spinach leaves of approximately 2 - 3 cm, containing one drop of 1 mg of each type of oils samples mentioned above was served at room temperature in a randomized order. Every panelist evaluated all the types of samples in a randomized order and assigned a numerical value from 1 (*imperceptible*) to 5 (*extremely intense*) for odor, followed by mouth taste. Also, the overall acceptability was analyzed by every participant who was asked to give a score [12, 13], from 1 (*dislike extremely*), a neutral intermediate category 4 (*neither like nor dislike*) and 7 (*like extremely*).

Statistical analysis

Means of peroxide and acidity values of oils (after having accelerated the storage of samples) were compared by using one-way analysis of variance (ANOVA), in order to assess significant differences among samples. Principal component analysis (PCA) and hierarchical cluster analysis (HCA) of data was computed for sensory and hedonic analysis of oil samples. All the analyses were performed by using the software program XLSTAT™ (Addinsoft©, U.S.A.).

RESULTS AND DISCUSSION

Total polyphenol content and antioxidant activity of basil, rosemary and thyme essential oils

Total phenol content was calculated from the standard curve of gallic acid ($y = 0.27x - 0.022$, $r^2 = 0.9929$) and expressed in $\mu g \cdot mL^{-1}$ samples and its values are:

27.58 μg·mL^{-1} for thyme oil, 33.12 μg·mL^{-1} for rosemary oil and 9.60 μg·mL^{-1} for basil oil.

The DPPH method was used to evaluate the antioxidant capacity of basil, rosemary and thyme essential oils in comparison with known synthetic antioxidant *L(+)*-ascorbic acid. The disappearance of the DPPH radical based on the absorbance at 518 nm wavelength can be monitored by decreased optical density. Figure 1 shows the spectrum in the VIS range of the DPPH radical in presence of 0.3 μg·mL^{-1} essential oils of thyme, basil and rosemary respectively. Based on their antioxidant capacity, spice essential oils can be sorted in descending order: thyme (*Thymus vulgaris*) > basil (*Ocimum basilicum*) > rosemary (*Rosmarinus officinalis*).

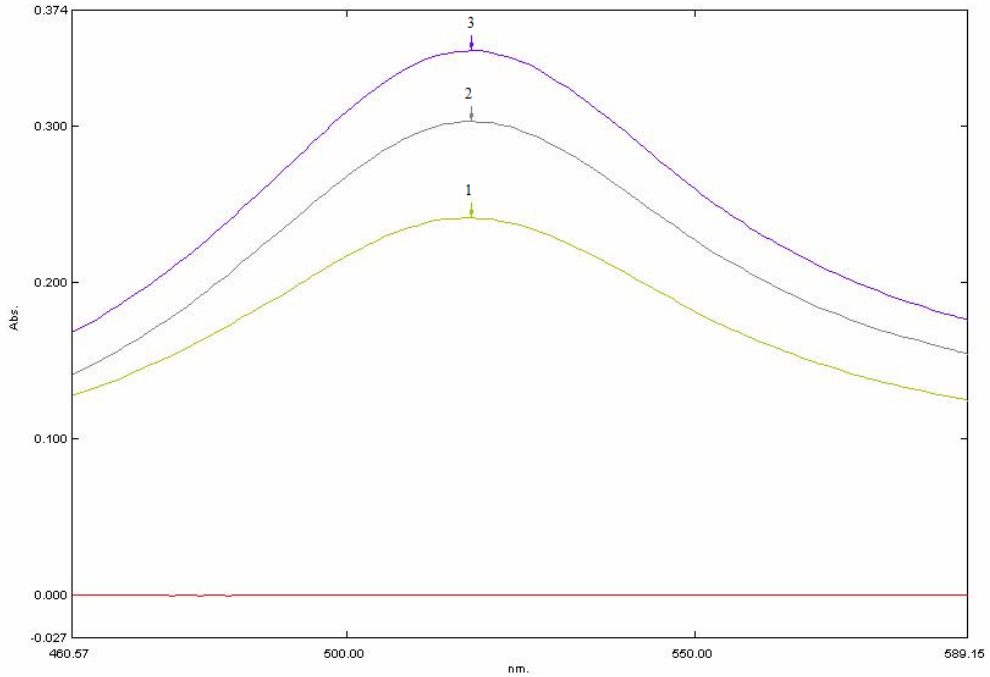


Figure 1. *Spectrum in the VIS range of the DPPH radical in presence of 0.3 μg·mL^{-1} essential oils of: 1 – thyme, 2 – basil, 3 - rosemary*

The DPPH radical scavenging activities of all the essential oils (basil, rosemary and thyme) increased with the increase of concentration.

Antioxidant capacities in series of concentrations of basil, rosemary and thyme essential oil and ascorbic acid were used to calculate the effective relative concentration EC_{50}. The concentration of essential oils that caused 50 % neutralization of DPPH radicals (EC_{50} values), were calculated from the plot of inhibition percentage against concentration. A higher DPPH radical scavenging activity was associated with a lower EC_{50} value. EC_{50} values of scavenging DPPH radicals for basil, rosemary and thyme essential oils were 5.718 ± 0.1 μg·mL^{-1}, 9.423 ± 0.06 μg·mL^{-1} and 3.067 ± 0.09 μg·mL^{-1}, respectively, while ascorbic acid had an EC_{50} of 161.578 ± 0.03 μg·mL^{-1}.

The results are consistent with previous data reporting antioxidant activity of essential oils of basil [14, 15], rosemary [16] and thyme [17], respectively. EC_{50} values generally vary considerably among studies, which can be explained by the different chemical compositions of essential oils of basil, rosemary and thyme, due to different

environmental and genetic factors, different chemotypes and the nutritional status of the plants.

Peroxide index and acidity of oils

Oil samples of sunflower, corn and grape seed before and after storage (4 days in an oven at a temperature of 60 °C) were analyzed taking into consideration the influence of temperature on the oxidation reaction.
The experimental determinations of the peroxide and acidity of oils were made after accelerated storage of samples without and with essential oils addition, at different concentrations (25 mg·kg^{-1} or 50 mg·kg^{-1}).
The initial edible oil samples acidity decreases in the following order: sunflower oil, corn oil, grape seeds oil and the peroxide value (PV) varies in the same order, characterizing the stability of each type of oil. The storage in oven for 4 days at 60 °C of the three types of oil samples without or with addition of essential oils influences the acidity and peroxide value. The results are shown in the Table 1 and Table 2, respectively.

Table 1. *Variation of peroxide index PV (mEq of O_2·kg^{-1} oil) without or with essential samples of oil addition after accelerated storage of samples (4 days in oven at 60 °C)*

Type of edible oil	Essential oil added [mg·kg^{-1}]	Peroxide index PV [mEq of O_2·kg^{-1} oil]		
		Rosemary oil	Thyme oil	Basil oil
Sunflower oil	0	11.80 ± 0.10		
	25	9.95 ± 0.09^{a*}	10.00 ± 0.09	10.20 ± 0.09
	50	9.94 ± 0.09^{a*}	9.97 ± 0.09^{b*}	9.98 ± 0.09^{b*}
Corn oil	0	11.00 ± 0.09		
	25	9.20 ± 0.08	9.50 ± 0.08^{c*}	9.50 ± 0.08^{c*}
	50	9.10 ± 0.08	9.40 ± 0.08^{d*}	9.40 ± 0.08^{d}
Grape seeds oil	0	9.00 ± 0.08		
	25	7.60 ± 0.05^{e*}	7.90 ± 0.07	8.00 ± 0.07
	50	7.50 ± 0.06^{e*}	7.70 ± 0.07	7.80 ± 0.05

Mean values ± standard deviation (n = 3); in the same type of edible oil, means with the same superscript letter a-e are not significantly different from one another (with a significance level *p < 0.05) according to Tukey's test applied after ANOVA.

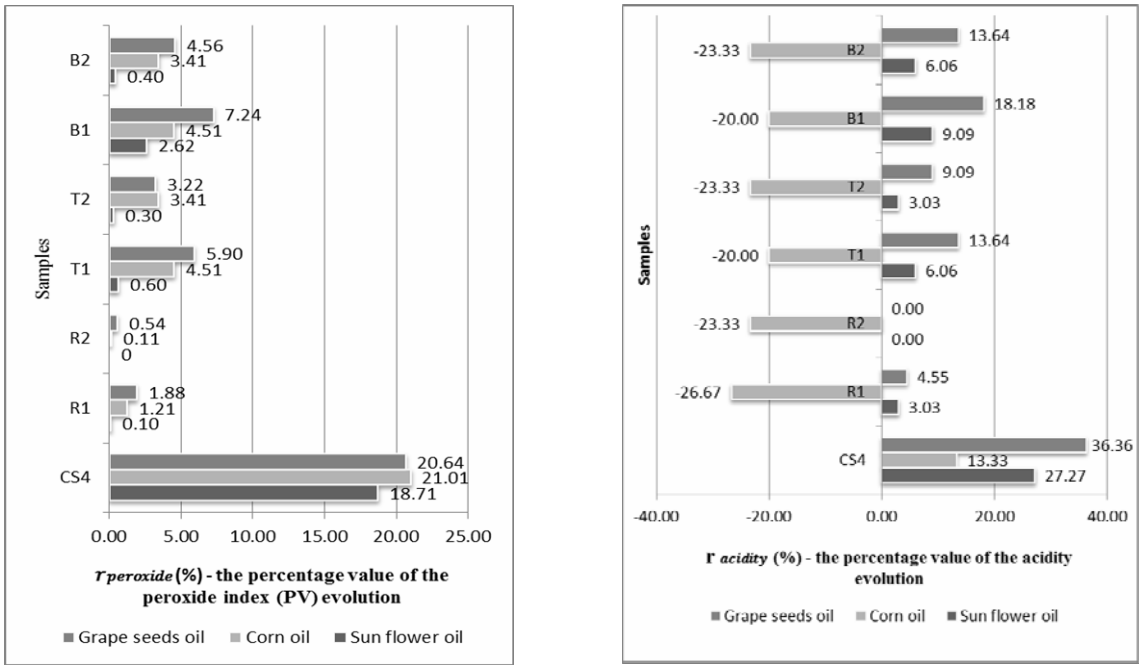
The acidity of sunflower oil increased by 27.2 %, that of corn oil by 24.3 % and that of grape seed oil by 36.3 %. The peroxide value (PV) increased by 18.7 % in sunflower oil, by 21 % in corn oil and 20.6 % in grape seed oil as compared to reference samples. The addition of essential oils of various concentrations in vegetable oil samples (sunflower oil, corn oil and grape seed oil) leads to a significant decrease in the values of acidity between 23.3 % - 26.7 % and PV between 18.6 % - 20 %.
The most effective was the addition of rosemary oil in a concentration of 50 mg·kg^{-1} in grape seed oil followed by sunflower and corn whose additions maintain acidity and PV values very close to those of the initial samples.
After accelerated storage of samples, the minimum increase of peroxide index and acidity was obtained for 50 mg·kg^{-1} rosemary oil in every type of edible oils (sun flower, corn or grape seeds oils). Grape seeds oil with 50 mg·kg^{-1} rosemary oil is the most stable one.

Table 2. *Variation of free acidity (oleic acid % by weight) of oil without or with essential samples of oil addition after accelerated storage of samples (4 days in oven at 60 °C)*

Type of edible oil	Essential oil added [mg·kg^{-1}]	Free acidity [oleic acid % by weight]		
		Rosemary oil	Thyme oil	Basil oil
Sunflower oil	0	0.42 ± 0.03		
	25	0.34 ± 0.01^{a**}	0.35 ± 0.02^{b*}	0.36 ± 0.01
	50	0.33 ± 0.01	0.34 ± 0.01^{a**}	0.35 ± 0.02^{b*}
Corn oil	0	0.34 ± 0.03		
	25	0.23 ± 0.01^{c**}	0.24 ± 0.02^{d*}	0.24 ± 0.01^{d*}
	50	0.23 ± 0.01^{c**}	0.23 ± 0.01^{c**}	0.23 ± 0.01^{c**}
Grape seeds oil	0	0.30 ± 0.03		
	25	0.23 ± 0.01	0.25 ± 0.02^{e*}	0.26 ± 0.02
	50	0.22 ± 0.01	0.24 ± 0.02	0.25 ± 0.02^{e*}

Mean values ± standard deviation (n = 3); in the same type of edible oil, means with the same superscript letter a-e are not significantly different from one another (with a significance level *p < 0.05 or **p < 0.01) according to Tukey's test applied after ANOVA.

The evolution of percentage $r_{peroxide}$ defined in formula (2) and $r_{acidity}$ defined in formula (3) can be observed in the Figure 2a and Figure 2b.



(a) $r_{peroxide}$ *(%)* ***(b)*** $r_{acidity}$ *(%)*

Figure 2. *The variation percentage for $r_{peroxide}$ and $r_{acidity}$ after 4 days, at 60 °C*

We noted samples by CS4 (control samples after 4 days, at 60 °C), B1 and B2 (edible oils with 25 mg·L^{-1}, respectively 50 mg·L^{-1} basil oil added), T1 and T2 (edible oils with 25 mg·L^{-1}, respectively 50 mg·L^{-1} thyme oil added), R1 and R2 (edible oils with 25 mg·L^{-1}, respectively 50 mg·L^{-1} rosemary oil added).

A significant decreasing effect on the PV percentage value $r_{peroxide}$ (Figure 2a) can be observed using one-way analysis of variance (ANOVA, with a significance level

$p < 0.05$), obtained by the addition of essential oils in sunflower oil and also, on the acidity percentage value $r_{acidity}$ (Figure 2b).

Evaluation of sensorial characteristics and hedonic perception of samples

During the sessions of analysis, the assessors determined the intensity of taste and odor for each sample through objective evaluations. The results of evaluation were written down by every panelist for all samples. We used the following abbreviations: SFOB - sunflower oil with basil oil, SFOT - sunflower oil with thyme oil, SFOR - sunflower oil with rosemary oil, GSOB - grape seeds oil with basil oil, GSOT - grape seeds oil with thyme oil, GSOR - grape seeds oil with rosemary oil, COB - corn oil with basil oil, COT - corn oil with thyme oil, COR - corn oil with rosemary oil.
Data sets were evaluated using standard descriptive statistics (average, standard deviation) and one-way analysis of variance (ANOVA). When ANOVA indicated a significant difference between samples ($p < 0.05$), Tukey's HSD was used to determine which samples differed significantly in the overall like. The results are reported in the Table 3.

Table 3. *Taste and odor profiles of samples*

Samples of edible oils with essential oils	Bread taste	Bread odor	Spinach taste	Spinach odor
SFOB	3.35 ± 1.49	3.15 ± 1.23	2.75 ± 1.52^{c}	$2.70 \pm 1.17^{b,c}$
SFOT	4.15 ± 0.98^{1}	3.15 ± 1.53^{2}	2.85 ± 1.14^{c}	$2.75 \pm 1.33^{b,c}$
SFOR	4.25 ± 1.21^{1}	3.70 ± 1.30^{1}	$2.50 \pm 1.24^{c,2}$	$2.35 \pm 1.23^{c,2}$
GSOB	3.90 ± 1.55^{1}	3.30 ± 1.63^{1}	$4.00 \pm 1.26^{a,1}$	$3.65 \pm 1.66^{a,b,1}$
GSOT	3.20 ± 1.58^{1}	2.75 ± 1.48^{2}	$3.80 \pm 1.44^{b,1}$	$4.00 \pm 1.12^{a,1}$
GSOR	3.15 ± 1.18^{2}	2.75 ± 1.33^{2}	$3.85 \pm 1.18^{b,1}$	$3.75 \pm 1.02^{a,b,1}$
COB	3.90 ± 0.72^{1}	2.70 ± 0.92^{2}	3.40 ± 0.94	3.30 ± 1.03
COT	3.90 ± 0.85^{1}	3.00 ± 1.21^{2}	2.90 ± 0.97^{2}	3.10 ± 1.07^{2}
COR	4.00 ± 0.65^{1}	2.90 ± 1.41^{2}	2.90 ± 1.41^{2}	$3.50 \pm 1.47^{b,1}$

Mean values ± standard deviation of scores given for the intensity of taste and odor (n = 20). Different superscripts letters (a-c) within columns and different numbers (1 and 2) within rows indicate statistically significant differences (*p <0.05) according to Tukey's test applied after ANOVA.

Scores between 4 (*very intense*) and 5 points (*extremely intense*) were obtained from tasting bread with oil samples of type: SFOR, SFOT and COR. For the spinach leave with oils samples taste, good scores (between 4 and 5 points) were obtained by adding oil samples of type: GSOB, GSOR and GSOT.
A significant correlation (with a significance level $p < 0.05$) between taste of bread oil samples has been noticed, the correlation matrix showing a high level of positive correlation, 0.589, between taste of bread with GSOT or GSOB and a negative correlation, -0.528, between taste of bread with GSOB or SFOB. As regards odor of bread oil samples, a high level of positive correlation, 0.688, between odor of bread with GSOT and GSOB, and a negative correlation, -0.531, between taste of bread with COT and SFOB have been registered. A significant correlation between taste of spinach leaves with oil samples was found between taste of spinach with SFOT and SFOB, 0.557, and a negative correlation, - 0.763, between taste of spinach with COT and COB.

A high level of positive correlation, 0.521, between odor of spinach leaves with SFOT and SFOB and a negative correlation, - 0.597, between taste of bread with GSOT and SFOT has been registered.

Principal component analysis (PCA) was performed [18] on the scores of taste and odor of bread and spinach leaves, respectively, with oil samples, given by all 20 panelists (Figure 3).

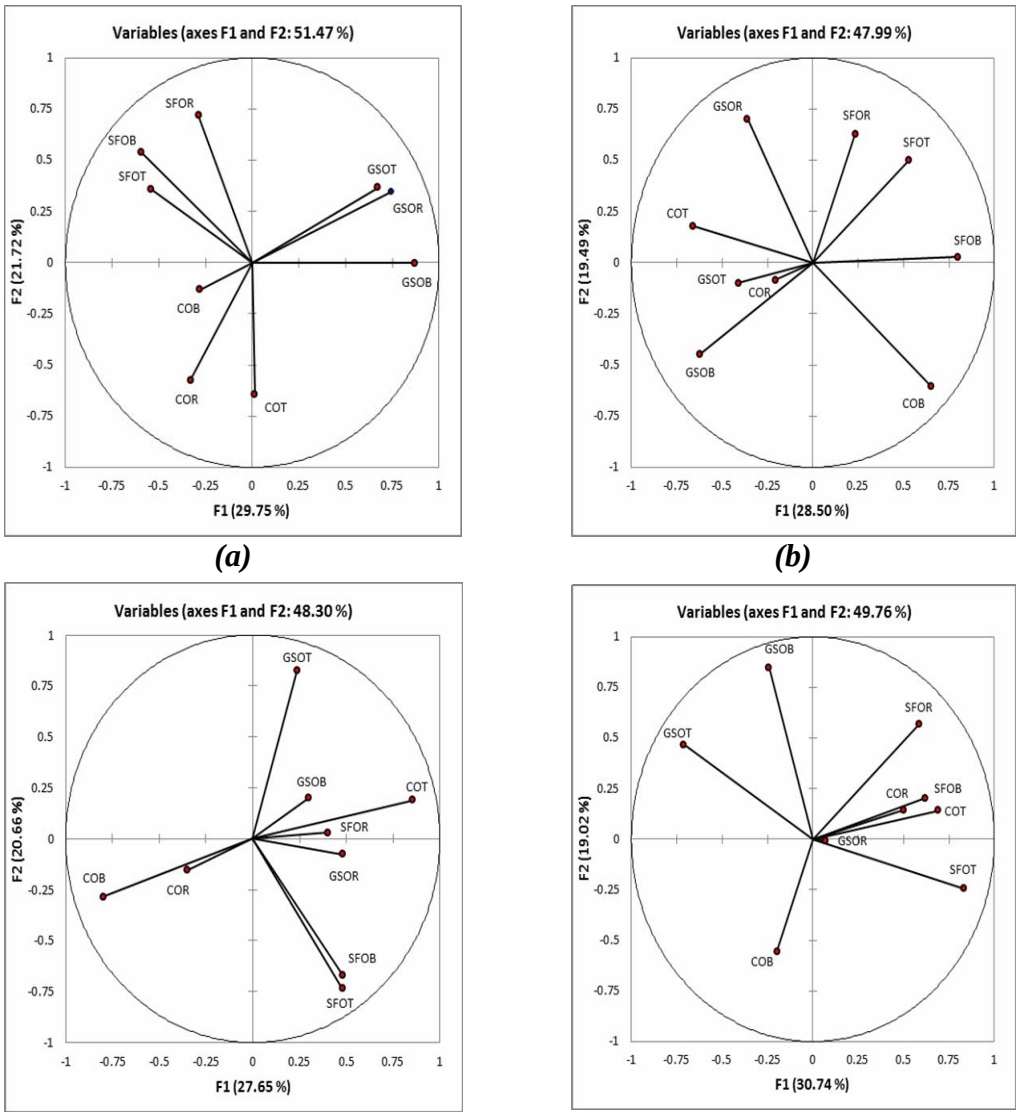


Figure 3. *PCA for bread taste (a) and bread odor (b), spinach leaves taste (c) and spinach leaves odor (d) with oil samples*

Two principal components (PCs) accounting for 51.47 % of the variation of taste of bread can be observed in Figure 3a. The first factor (F1) explains 29.75 % of the total variance with significant parameters GSOB and GSOR. The second factor (F2) explains 21.72 % of the total variance with a significant parameter SFOR. For the variation of odor of bread, PCs account for 47.99 % (Figure 3b). The first factor (F1) explains 28.50 % of the total variance with the significant parameter SFOB. The second factor

(F2) explains 19.49 % of the total variance with a significant parameter GSOR. For the variation of fresh spinach leaves taste, PCs account for 48.30 % (Figure 3c). The first factor (F1) explains 27.65 % of the total variance with a significant parameter COT. The second factor (F2) explains 20.66 % of the total variance with a significant parameter. For the variation of the fresh spinach leaves odor, PCs accounting 49.76 % (Figure 3d). The first factor (F1) explains 30.74 % of the total variance with a significant parameter SFOT. The second factor (F2) explains 19.02 % of the total variance with a significant parameter GSOB.

In order to group the products sharing similar sensory features, a hierarchical cluster analysis (HCA) was performed on scores means of samples [18]. The resulting dendrograms are shown in the Figure 4.

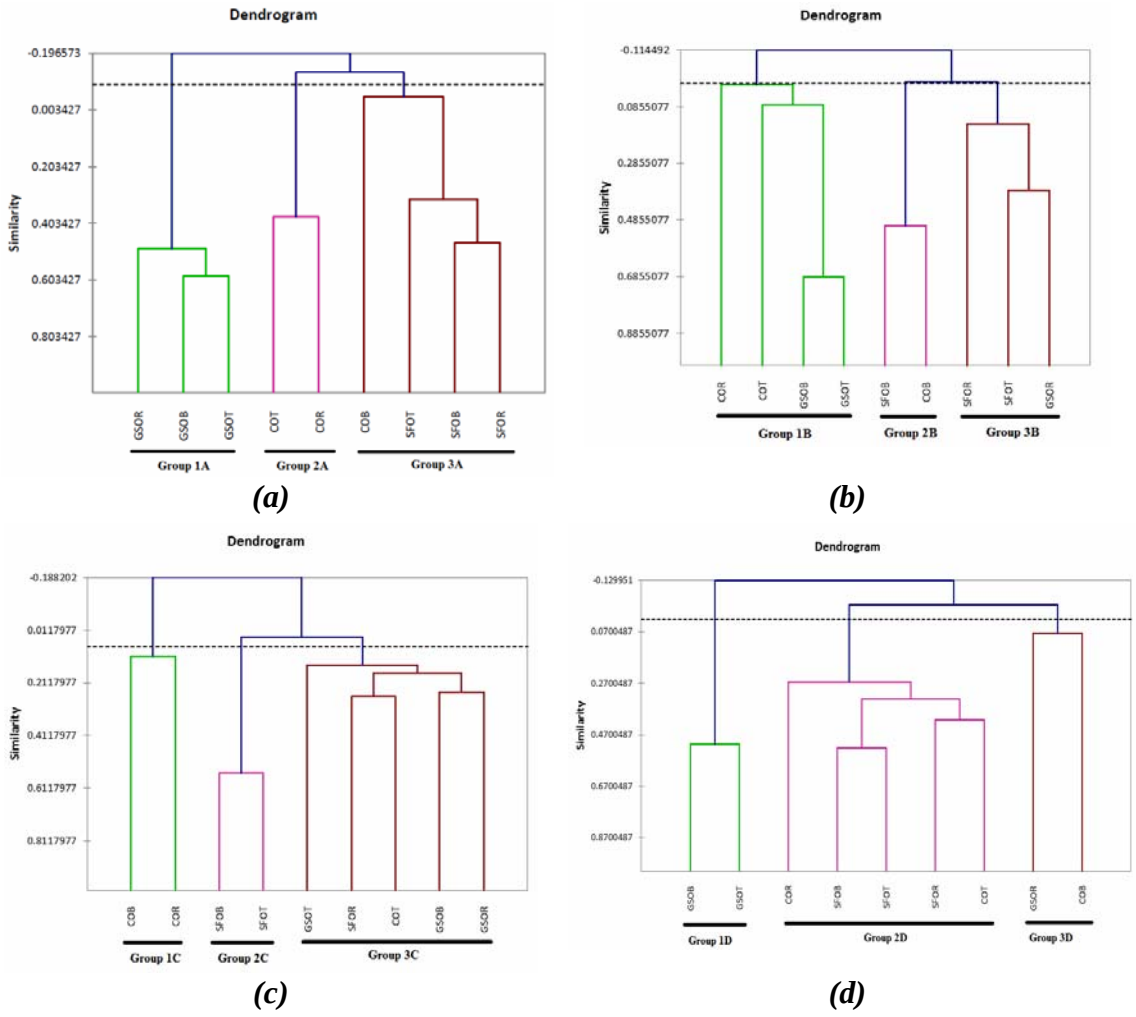


Figure 4. *Hierarchical cluster analysis (HCA) for bread taste (a) and bread odor (b), spinach leave taste (c) and spinach leave odor (d) with oil samples*

Basically, in every situation three groups have been identified in all samples. For bread taste with oil samples, groups are: 1A (GSOR, GSOB, GSOT), 2A (COT, COR) and 3A (COB, SFOT) (Figure 4a). For bread odor with oil samples, groups are: 1B (COR, COT, GSOB, GSOT), 2B (SFOB, COB) and 3B (SFOR, SFOT, GSOR) (Figure 4b). For spinach leave taste with oil samples, groups are: 1C (COB, COR), 2C (SFOB, SFOT)

and 3C (GSOT, SFOR, COT, GSOB, GSOR) (Figure 4c). For spinach leave odor with oil samples, groups are 1D: (GSOB, GSOT), 2D (COR, SFOB, SFOT, SFOR, COT) and 3D (GSOR, COB) (Figure 4d).
The results of the hedonic evaluation were written down by every panelist for all samples. The results are reported in the Figure 5.

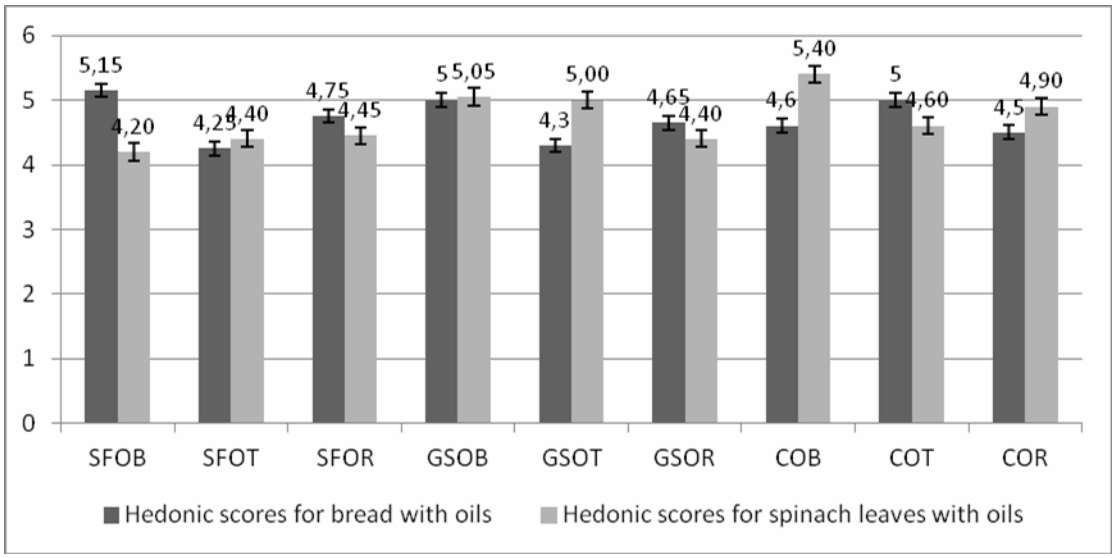


Figure 5. *Results of the hedonic evaluation*

Scores for overall like of bread and fresh spinach leaves with oil samples are higher than 5 points (between like slightly and like very much) for bread with oil samples SFOB, GSOB and COT, while for spinach leaves these scores are obtained for oil samples COB, GSOT and GSOB.

CONCLUSIONS

This study led to interesting results in the field of oxidation stability, during storage of some type of oils (sunflower, corn and grape seed oils respectively) in the presence of antioxidants in essential oils of rosemary, thyme and basil, which recommend the use of these plant extracts as additives in edible oils in view of increasing their oxidative stability.
The addition of very small amounts of essential oils determines positive change in the sensory and hedonic perception of edible oil. The perception of rosemary or thyme essential oil taste of bread varies between *very* and *extremely intense* if they are added in sunflower oil, in corn oil respectively, while the perception of basil, rosemary or thyme essential oil taste of fresh spinach leaves varies between *very* and *extremely intense* if they are added in grape seed oil. Also, the perception of basil, rosemary or thyme essential oil odor of bread varies between *intense* and *very intense* if they are added in sunflower oil, while the perception of thyme essential oil odor of fresh spinach leaves is *intense* if it is added in grape seed oil.
The results confirm that the extracts of rosemary, basil and thyme oils can be used as antioxidants in edible oils instead of synthetic antioxidants as taste and odor improvers.

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