EFFECT OF ADDING ESSENTIAL OILS OF CARAWAY AND ROSEMARY ON VOLATILE AROMA COMPOUNDS DERIVED FROM STORED VACUUM PACKAGED MINCED TURKEY MEAT*

Magdalena Michalczyk^{1*}, Paweł Satora², Joanna Banaś¹, Grzegorz Fiutak¹

¹Department of Biotechnology and General Technology of Food, Faculty of Food Technology,
University of Agriculture in Krakow, Balicka 122, 30-149 Kraków, Poland

²Department of Fermentation Technology and Microbiology, Faculty of Food Technology,
University of Agriculture in Krakow, Balicka 122, 30-149 Kraków, Poland

*Corresponding author: magdalena.michalczyk@urk.edu.pl

Magdalena Michalczyk <https://orcid.org/0000-0002-7962-8196>

Paweł Satora <https://orcid.org/0000-0003-4091-5822>

Joanna Banaś <https://orcid.org/0000-0002-1354-0765>

Grzegorz Fiutak <https://orcid.org/0000-0001-7781-7922>

Abstract

Changes in the odor of meat during its storage are one of the basic indicators affecting its assessment and possible disqualification. The aim of the study was to determine whether the addition of essential oils may affect the composition and concentration of volatile compounds included in the aroma of stored turkey meat. We investigated the effect of adding essential oil (EO) of caraway (0.02% v/w), rosemary (0.02% v/w) and a mixture of the two (0.01% each) on the composition of volatile compound fractions formed during 10-day storage of vacuum-packed minced turkey meat. The EOs used were also evaluated for their influence on microbial contamination (total viable count and lactic acid bacteria count), sensory quality (odor and taste) and the level of fat rancidity (acid value, peroxide value and p-anisidine value) and pH in chill-stored samples. In terms of sensory indicators, the greatest beneficial effect of adding EOs was noted in the odor of raw meat. Use of the HS-SPME/GC-MS (headspace-solid phase microextraction/gas chromatography-mass spectrometry) method showed that the addition of essential oils significantly reduced the amounts of benzeneacetaldehyde, 2-octenal and ethyl 2-methyloctanoate compared with the control sample. In addition, in the presence of essential oils of rosemary and caraway, decreases were noted in benzaldehyde and 9-octadecenal, respectively. These changes may potentially affect the reception of the odor. There was a beneficial effect of the EOs in reducing the levels of fat oxidation indicators, including peroxides. However, the oils at applied concentrations had no significant effect on the total viable count and LAB count.

Key words: volatile aroma compounds, essential oil, poultry meat, storage, antioxidative effect

*This research was financed by the Ministry of Science and Higher Education of the Republic of Poland.

Turkey meat is popular due to its relatively low price, low fat content and the fact that it is sensorially acceptable. In the world's poultry production, it takes second position after broiler meat (Oz and Yuzer, 2017). Wong et al. (1993) reported that fat content in the retail raw ground turkey samples analyzed by them ranged from 7.2 to 10.8%. In cited research total content of polyunsaturated fatty acids, expressed as weight percentage of total fatty acid methyl esters, ranged from 24.6 to 32.5% and linoleate 18:2n-6 was the major polyunsaturated acid. Total lipid content determined by these authors in light turkey meat, in dark meat, and in skin was $2 \text{ g} \cdot (100 \text{ g})^{-1}$, $5.1 \text{ g} \cdot (100 \text{ g})^{-1}$, and $39.8 \text{ g} \cdot (100 \text{ g})^{-1}$, respectively. Fatty acids not only have an effect on the nutritive value, sensory quality and stability of fat during meat storage, but are also the main source for the formation of volatile compounds, with a crucial role of unsaturated fatty acids (Van Ba et al., 2013). Glucose and amino acids are also odor-forming substrates (Corral et al., 2013; Nychas et al., 1988). Transformations of substrates take place due to the activity of meat enzymes, microbial-derived ones and as a result of chemical reactions, including oxidation.

According to Ahn et al. (1999), who applied a purge-and-trap/GC method, volatiles in raw turkey thigh meat included: hexanal, 2-butanone, 2-propanone, tetradecane, dimethylheptane, trimethylhexane, tridecane, 2-methylbutane, heptane, pentanal, 1-pentanol, nonanal, 1-heptanol, heptanal and propanal. The authors noted that these substances were associated mainly with the fat fraction, which in turn was chiefly due to the sampling method. The composition of determined volatile fraction is affected by both species of animal and its diet and the method of sample preparation (Ahn et al., 1999, 2006).

Studies on extending shelf life of minced meat include the use of additives and modifications of packaging methods. Natural substances that can be used in preserving minced meat include essential oils (EOs) of plant origin. Many of them have antimicrobial and antioxidant properties (Bulut et al., 2009; Othman et al., 2016). Studies on the use of these substances concentrate on the extension of meat durability and the reduction of the pathogen proliferation risk (Vasilatos and Savvaidis, 2013; Boskovic et al., 2017; Irkin and Esmer, 2010). The maximum concentrations of EOs, considered as a preserving addition to meat, are limited not only by the cost of these substances, but above all by the sensory acceptability threshold. Effective concentrations are often higher than sensorily acceptable ones (Nazer et al., 2005). Besides concentration, combinations of specific essential oils and types of meat may also be a barrier to sensory acceptance. In this study, the EOs used were selected as acceptable in turkey meat in the preliminary sensory evaluation. One of the effects of adding EOs to meat may be an improvement in its odor during refrigerated storage (Govaris et al., 2010; Chouliara et al., 2007; Shahbazi et al., 2018; Skandamis and Nychas, 2001). The effect observed may be due to both masking the spoiled meat odor by the added volatile substances and the direct influence of EO components on the chemical, biochemical and microbial reactions, resulting in the formation of components of the odor of spoilage.

The aim of the study was to determine whether the addition of essential oils of rosemary and caraway affects the composition of the volatile compound fraction of stored turkey meat. Due to the fact that odor is also affected by the activity of

microorganisms and fat oxidation, the extent of changes in these quality factors was also assessed.

Material and methods

Material

The raw material was turkey thighs. Meat was collected one day after slaughtering. The raw material was next minced using a meat grinder ($\varnothing$ 3 mm) and divided into four batches. One was a control (without additives). The remaining three were mixed with EOs, one with EO of caraway (*Carum carvi* L.) (0.02% v/w), the other with oil of rosemary (*Rosmarinus officinalis* L.) (0.02% v/w) and the last one with a mixture of the two (0.01% each). The selection of oils and their combinations was based on previous sensory evaluations, during which EOs were added to meat. The maximum concentration was also established on the same basis. 100% natural EOs of caraway and rosemary were purchased from a shop and their compositions were established by the HS-SPME/GC-MS method (Table 3). 0.4 kg portions of the products were vacuum packaged using a packaging machine (Vac-Star 1000, Switzerland) and then stored at $1\pm 2^{\circ}\text{C}$ in darkness. Analyses were performed in fresh raw material and after 10 days of storage.

Methods

Sensory evaluation

The odor and color of raw meat as well as the color, odor and taste of cooked meat were assessed by means of sensory evaluation. Samples, in the form of 40 g meatballs, were cooked in water for 15 min and assessed on the basis of the previously compiled table. A score of 5 points was assigned to the highest quality, 3 points was the acceptability threshold, while a score of 2 points was assigned to the poorest (and unacceptable) quality. Evaluation was conducted by a trained 7-member sensory panel.

Rancidity indicators and pH analysis

The anisidine value (p-AV) was determined using the methodology described in Cd 18–90 (AOCS, 2004), extracting the secondary fat oxidation products with isooctane, and then measuring the absorbance of their reaction product with p-anisidine at $\lambda = 350$ nm. The peroxide value (PV) was determined using the Cd 8b-90 method (AOCS, 2004). Fat fraction extracts containing glacial acetic acid and potassium iodine solution were titrated with sodium thiosulfate in the presence of starch. The results of the determinations were expressed in meq of active oxygen per kg of product. The acid value (AV) was determined based on the Cd 3d-63 standard (AOCS, 2004), titrating the samples with NaOH solution in the presence of phenolphthalein as an indicator. This value was expressed as the number of mg of free fatty acids per g of product. pH was measured using HI 9025 (Hanna Instruments) pH meter.

Microbiological analysis

Samples for microbiological analyses were placed in sterile bags with the dilution fluid, homogenized, and then a series of dilutions were performed.

The total viable count (TVC) was determined on plate count agar (PCA), after incubation at 30°C for 72 h, in accordance with the Polish Standard (PN-ENISO 4833-1:2013-12). Lactic acid bacteria were enumerated on de Man, Rogosa, and Sharpe (MRS) medium after 72 hours' incubation at 30°C (PN-ISO15214:2002).

Volatile compounds analysis

Commercially available, 100% natural EOs and meat-derived volatile compounds were analyzed by means of the headspace solid phase microextraction and gas chromatography–mass spectrometry (SPME-GC-MS) method. For the determination of volatiles, 2 mL of saturated saline with an internal standard solution (5 mg·L⁻¹ 4-methyl-2-pentanol and 0.05 mg·L⁻¹ ethyl nonanoate, Sigma-Aldrich) and a 10 µL sample of EO or a 0.5 g sample of turkey meat was placed in a 10 mL vial. The SPME device (Supelco Inc., Bellefonte, PA, USA) coated with PDMS (100 µm) fiber was first conditioned (250°C for 1 h) and next inserted into the headspace under stirring (300 rpm) for 30 min at 60°C. Subsequently, the SPME device was introduced into the injector port of the Agilent Technologies 7890B chromatograph system equipped with LECO Pegasus HT, High Throughput TOFMS, with a GERSTEL MultiPurpose Sampler (MPS), and was kept in the inlet for 3 min. The tested components were separated on a Restek Rtx-1 capillary column (nonpolar phase; Crossbond dimethyl polysiloxane; 30 m × 0.25 mm ID with 0.25 µm film thickness). Temperature of detection was 250°C and the following temperature program was used: 35°C for five minutes at an increment of 5°C·min⁻¹ to 110°C, then 40°C·min⁻¹ to 230°C and maintaining a constant temperature for five minutes. The carrier gas was helium at 1.0 ml·min⁻¹ constant flow. EIMS electron energy: 70 eV; ion source temperature and connection parts: 250°C. Analyte transfer was performed in splitless mode; the MSD was set to scan mode from $m/z = 40$ to $m/z = 400$.

The method was validated according to Silva-Flores et al. (2019). Compounds were identified using mass spectral libraries (<http://webbook.nist.gov/chemistry/>) and linear retention indices, calculated using a series of n-alkanes from C6 to C30.

The qualitative and quantitative identification of volatiles (α -pinene, eucalyptol, D-limonene, γ -terpinene, linalool, camphor, borneol, carvone, β -caryophyllene, ethyl acetate, ethyl octanoate, ethyl decanoate, ethyl dodecanoate, hexanol, hexanal, heptanal, nonanal, benzaldehyde; Sigma-Aldrich) was based on the comparison of retention times and peak surface area of sample and standard chromatograms. Other detected components were determined semi-quantitatively ($\mu\text{g}\cdot\text{kg}^{-1}$) by measuring the relative peak area of each identified compound, in relation to that of the internal standard.

Statistical analysis

All analyses were carried out three times. The significance of differences between means of volatile compounds was determined using one-way ANOVA and Duncan's test at $P < 0.05$, using SPSS 19.0 software. The significance of difference between

means of other indicators was determined using one-way ANOVA and Tukey's test at $P < 0.05$, using Statistica version 13 (TIBCO Software Inc., 2017).

Results

Sensory changes

After the storage period, the color of both raw and cooked meat remained unchanged and achieved the highest scores (5.0). The taste of cooked meat changed slightly in the case of the control; however, after the storage period it still scored 4.6, which is a good result. The samples with EOs were evaluated better and scored higher grades. The odor of cooked meat was also very stable and for the control sample at the end of the storage period still scored 4.5 and for samples with EOs the scores were higher. In contrast, the odor of raw meat changed significantly (Table 1). After 10 days of storage only the samples with added rosemary essential oil scored on average 3.0 points. The samples containing both essential oils or caraway essential oil scored slightly lower than the acceptability threshold (3.0), but significantly higher than the control probe.

Table 1. Changes in the count of microorganisms ($\log \text{cfu} \cdot \text{g}^{-1}$) and the odor (scores) of raw vacuum-packed minced turkey meat with or without addition of essentials oils, stored at $1-2^\circ\text{C}$

Sample	Storage time (days)	Total viable count	Lactic acid bacteria	Odor of raw meat
Control	0	4.73 a	4.11 a	5.0 a
Control	10	8.28 b	7.98 b	2.0 b
Caraway**	10	8.38 b	8.19 b	2.9 c
Rosemary**	10	8.31 b	8.15 b	3.0 c
Caraway and rosemary***	10	8.42 b	8.26 b	2.9 c

*Values in a column denoted with different letters are significantly different ($P < 0.05$).

**Concentration of essential oil: 0.02% v/w.

***Concentration of individual essential oil: 0.01% v/w.

Changes in fat rancidity indicators, meat pH and microbiological quality

The values of fat quality indicators are given in Table 2. The acid value allows the assessment of the extent of hydrolytic changes occurring in the fat fraction. The EOs added individually to meat had no significant effect on acid value, whereas a small positive effect was observed in the case of their mixture, which is consistent with changes in the pH value (Table 2). The effect of adding EOs was more visible with regard to indicators of oxidative changes. The peroxide value determines the amount of peroxides and hydroperoxides. The addition of rosemary oil, in the concentration of both 0.01% and 0.02%, allowed the initial value of this parameter to be maintained until the end of the storage period. In contrast, in the samples containing only essential oil of caraway, there was an increase in PV, but it was significantly lower than in the control sample. The anisidine value determines the amount

of aldehydes resulting from the decomposition of hydroperoxides, mainly 2-alkanals reacting with p-anisidine. As for changes in this value, the addition of both EOs had a positive effect on fat stability; the effect was stronger in meat with added essential oil of caraway. The pH was slightly reduced in all stored samples of minced meat. The smallest change in the pH value compared to fresh meat was noted in the samples with a mixture of EOs. The essential oils used had no inhibitory effect on TVC and LAB count (Table 1). Both TVC and LAB exceeded the threshold of 7 log cfu/g.

Table 2. Changes in values of rancidity indicators and pH of raw vacuum-packed minced turkey meat with or without addition of essentials oils, stored at 1–2°C

Sample	Storage time (days)	Acid value (mg·g ⁻¹ of meat)	Peroxide value (meq·kg ⁻¹ of meat)	p-Anisidine value	pH
Control	0	3.9 a	3.0 a	0.11 a	6.3 a
Control	10	4.7 b	6.0 b	0.97 b	6.1 b
Caraway**	10	4.6 b	4.4 c	0.46 d	6.1 b
Rosemary**	10	4.6 b	3.0 a	0.63 c	6.1 b
Rosemary and caraway***	10	4.3 a	2.8 a	0.58 e	6.2 c

*Values in columns denoted with different letters are significantly different ($P < 0.05$).

**Concentration of essential oil: 0.02% v/w.

***Concentration of individual essential oil: 0.01% v/w.

Composition of EOs

The composition of dominant volatile compounds in EOs used in minced turkey meat, established by the SPME-GC-MS method, is presented in Table 3. The monoterpene carvone (over 60% of the relative essential oil quantity), followed by trans-dihydrocarvone, D-limonene, carvacrol and p-cymenene were the main components of caraway EO. EO of rosemary had a larger amount of ingredients with significantly smaller individual percentages. In this EO, eucalyptol, camphor, β -caryophyllene and borneol were found in the largest relative quantities.

Changes in concentration of the meat-derived volatile compounds

Changes in concentration of the meat-derived volatile compounds are shown in Table 4. At the end of the storage period, in the meat without EOs there occurred, among others, 2,3-butanedione (diacetyl), ethyl acetate, ethyl decanoate, ethyl dodecanoate, ethyl tetradecanoate, ethyl hexadecanoate, as well as benzeneacetaldehyde. There was also an increase in the concentration of ethyl octanoate and dimethylphenethyl acetate. In the case of the above-described diacetyl, ethyl acetate, ethyl octanoate, ethyl tetradecanoate, ethyl dodecanoate, and ethyl hexadecanoate, there was no limiting effect of adding EOs; sometimes even a slight increase was recorded compared to the control. Stored samples with rosemary essential oil did not contain benzaldehyde, benzeneacetaldehyde and ethyl 2-methyloctanoate. Benzeneacetaldehyde was found only in control samples and those with addition of caraway essential oil, both after storage. On the other hand, the addition of EO of caraway contributed to the reduction of the amounts of 9-octadecenal, 2-octenal and ethyl 2-methylcyclohexanoate. In turkey samples with the addition of EOs, a lower content of hexathiane and cyclic octaatomic sulfur was also found.

Table 3. Relative aroma component composition in rosemary and caraway essential oil

RI*	Compound	% Content	
		rosemary	caraway
1	2	3	4
918	Tricyclene	0.29	–
935	α -Pinene	3.27	0.03
951	Camphene	2.51	0.02
980	β -Pinene	3.56	0.09
984	β -Myrcene	1.65	0.12
994	α -Phellandrene	0.63	–
1018	Eucalyptol	17.89	–
1024	p-Cymene	–	0.83
1029	D-Limonene	–	8.27
1049	γ -Terpinene	1.25	0.20
1067	p-Cymenene	0.44	2.20
1081	Terpinolene	0.83	0.73
1084	Linalool	2.23	1.54
1114	Camphor	17.33	1.38
1145	Borneol	6.38	–
1158	Terpinen-4-ol	1.15	0.88
1169	α -Terpineol	1.89	–
1200	trans-Dihydrocarvone	–	11.28
1209	Isoborneol	0.35	–
1243	Carvone	–	62.29
1250	Eucarvone	–	2.30
1266	Bornyl acetate	5.73	–
1296	Carvacrol	–	3.45
1308	Cubebene	0.56	–
1318	α -Bergamotene	0.30	–
1339	Clovene	0.27	–
1350	Limonene glycol	–	1.97
1372	Longicyclene	0.69	–
1376	α -Copaene	1.17	–
1378	2-Allyl-4-methylphenol	–	1.61
1384	β -Bourbonene	1.11	–
1407	Longifolene	0.94	–
1421	β -Caryophyllene	15.78	0.53
1438	Aromandendrene	1.12	–
1457	Humulene	3.36	0.20

Table 3 – contd.

1	2	3	4
1471	γ -Muurolene	1.19	–
1492	α -Selinene	0.18	–
1494	Garmacrene D	0.15	–
1496	α -Muurolene	1.08	–
1503	β -Bisabolene	0.90	–
1511	Calamenene	0.55	–
1514	δ -Cadinene	1.44	–
1527	Cubenene	0.31	–
1540	α -Calacorene	0.13	–
1558	Caryophyllene oxide	1.39	0.03

*Linear Retention Index.

Table 4. Volatile compounds derived from vacuum-packed, chill-stored turkey meat analyzed by the SPME-GC-MS method

Volatile compounds (mg·kg ⁻¹)	RI	Added essential oils				
		without additive		caraway	rosemary	caraway and rosemary
		time of storage (days)				
		0	10	10	10	10
1	2	3	4	5	6	7
Carbonyl compounds						
Hexanal	800	266.4 a*	241.6 a	289.3 a	256.0 a	396.3 a
Heptanal	901	5.9 a	8.9 a	11.1 a	9.4 a	16.2 b
Benzaldehyde	925	8.1 b	10.6 bc	14.2 c	0 a	0 a
2-Heptenal ¹	931	10.8 a	9.1 a	6.2 a	8.2 a	14.3 a
Octanal ¹	982	9.9 a	9.0 a	9.7 a	7.2 a	14.2 a
Benzeneacetaldehyde ¹	1004	0 a	48.5 c	34.2 b	0 a	0 a
2-Octenal ¹	1031	7.3 b	10.1 b	0.0 a	0.0 a	0.0 a
Nonanal	1083	16.7 a	17.0 a	24.0 b	24.2 b	29.6 b
Decanal	1209	10.4 a	11.5 a	9.7 a	14.7 a	9.6 a
2,4-Decadienal	1267	8.2 a	10.1 a	16.7 b	21.9 b	28.9 c
9-Octadecenal ¹	1999	9.2 b	10.4 b	0 a	13.3 b	7.8 ab
2,3-Butanedione (diacetyl) ¹	596	0 a	7.0 b	16.0 c	11.3 c	14.1 c
Geranyl acetone ¹	1453	26.9 b	12.4 ab	14.8 ab	20.5 ab	6.9 a
Alcohols						
1-Pentanol ¹	768	12.6 a	8.2 b	12.5 ab	13.1 a	16.3 a
1-Hexanol	865	7.2 ab	6.2 a	10.2 b	6.9 a	14.5 c
1-Octen-3-ol ¹	963	73.3 ab	64.9 a	77.6 ab	90.0 b	164.4 c

Table 4 – contd.

1	2	3	4	5	6	7
2-Octen-1-ol ¹	1058	4.2 a	6.0 a	5.3 a	4.9 a	6.8 a
2-Dodecen-1-ol ¹	1675	4.2 a	4.3 a	9.9 b	10.5 b	11.1 b
Esters						
Ethyl acetate	614	0 a	6.4 ab	2.6 a	6.3 ab	11.1 b
Ethyl octanoate	1205	18.8 a	52.9 b	48.2 b	67.5 b	50.6 b
Ethyl 2-methyloctanoate ¹	1231	105.6 a	97.8 a	0 b	0 b	0 b
Dimethylphenethyl acetate ¹	1297	18.4 a	45.8 b	40.5 b	57.5 c	33.8 b
Methyl diethyldithiocarbamate ¹	1377	12.5 a	14.1 ab	21.3 b	19.6 b	19.5 b
Ethyl decanoate	1384	0 a	19.4 b	31.2 c	26.3 bc	28.3 bc
Ethyl dodecanoate	1576	0 a	6.8 b	8.4 b	10.7 b	9.8 b
Ethyl tetradecanoate ¹	1777	0 a	6.9 b	9.5 c	11.0 c	9.4 c
Ethyl hexadecanoate ¹	1975	0 a	8.8 b	9.9 bc	11.4 c	11.6 c
Others						
2-pentylfuran ¹	976	70.7 a	69.9 a	69.0 a	92.9 b	133.6 c
Carbon disulfide ¹	517	60.1 a	50.1 a	57.2 a	38.2 a	54.8 a
Hexathiane ¹	1499	64.0 b	63.9 b	12.8 a	20.4 a	9.5 a
Cyclic octaatomic sulfur ¹	1989	62.0 b	55.2 b	12.2 a	20.2 a	10.5 a

*Values with different letters in the same row are significantly different ($P < 0.05$).

¹determined semi-quantitatively by measuring the relative peak area of each identified compound, according to the NIST database, in relation to that of the internal standard.

Discussion

The effect of EOs on the results of sensory evaluation was largest in the case of the odor of raw meat. Other authors also observed the beneficial effects of adding EOs on the odor of such products as minced sheep meat, chicken breast meat, minced camel meat and minced beef (Govaris et al., 2010; Chouliara et al., 2007; Shahbazi et al., 2018; Skandamis and Nychas, 2001). Data in Table 4 indicate that the effect obtained may result not only from the masking effect of these additives, but also from the fact that they can directly limit the formation of some compounds. After 10-day storage, in the turkey minced meat without EOs among others, some esters such as ethyl acetate and ethyl decanoate, and carbonyl compounds such as benzeneacetaldehyde and diacetyl appeared. The concentration of some other esters, such as ethyl octanoate, increased. The presence of these components should probably be attributed to the microbial activity (Costello et al., 2013). Most of them are formed as a result of esterification of adequate fatty acids derived from hydrolysis of the raw material's lipids by esterases of microbial origin. Esters can significantly affect the sensory profile, especially in the range of fruity off-flavors (Ercolini et al., 2010). Yano et al. (1995), who stored beef, pork and chicken thigh meat aerobically and in

vacuum conditions, noted the presence of ethyl acetate odor, considered as fruity, at the initial stage of bacterial spoilage and an increase in its concentration with the progress in deterioration. In their opinion, this constituent may be useful for assessing meat freshness. On the other hand, Olivares et al. (2012), who used SIFT-MS (Selected Ion Flow Tube Mass Spectrometry) in the headspace method, did not observe a significant increase in ethyl acetate in the stored raw beef samples originating from two suppliers. Moreover, they noted significant differences in the results of the quantification of volatile compounds in meat samples derived from both suppliers. In general, the results obtained in this study showed the highest proportion of carbonyl compounds in the volatile fraction of fresh and stored turkey meat. The predominant share of aldehydes in the volatile fraction of dry cured goose was also described by Ying et al. (2016). Aldehydes are the products, among others, of fatty acid oxidation via autooxidation or activity of microorganisms. Another source of these substances is amino acids, from which, depending on their structure (e.g. branched, aromatic or sulfur), are also formed respective alcohols, acids and sulfur volatile compounds (Corral et al., 2013). Another important substrate used by microorganisms is glucose, which is transformed, e.g. into lactic acid, CO₂, acetic acid, ethanol, and also diacetyl. The substrates for the latter could be also inosine and ribose (Nychas et al., 1988; Argyri et al. 2015; Pothakos, 2015). Diacetyl, described as giving a butter-like odor, may be produced by lactococci, *Leuconostoc* spp. and pediococci (Hoover, 2000), as well as *Brochothrix thermosphacta* (Pin et al., 2002; Illikoud et al., 2019). Moreover, Nieminen et al. (2016) observed that during the storage of raw pork in a modified atmosphere, diacetyl was one of the substances showing the highest correlations with the results of sensory evaluation and bacterial concentration. Hexanal, formed e.g. due to linoleic acid oxidation, was present in the highest concentration of all analyzed carbonyl compounds (Table 4). It is a component of the volatile compounds, which is broadly described in the literature. Its odor is described as fishy, grassy (Gu et al., 2013), or strong, rancid, and unpleasant (MacLeod and Coppock, 1976), and the odor threshold in meat is 0.015 ppm (Montel et al., 1998). According to Shahidi and Pegg (1994), this compound may undergo further oxidation or react with other meat ingredients, which results in limitations of its application as a lipid oxidation indicator. Studies on the storage of various meat species showed both an increase and decrease in the concentration of this substance after the storage period (Yang et al., 2018; Olivares et al., 2012; Argyri et al., 2015). One of the factors possibly affecting its concentration is the way of feeding animals. Descalzo et al. (2005) observed higher volatile levels of hexanal and several other aldehydes as well as thiobarbituric acid-reactive substances (TBARS) in fresh beef from grain-fed animals than in meat derived from pasture-grazing cattle. Bosse (née Danz) et al. (2017) reported that inoculation of cured loins with *Staphylococcus carnosus* reduced the formation of this substance and limited the formation of such fat oxidation products as nonanal, 2-pentanone and nonanone. The presence of EOs in turkey meat did not reduce the content of this constituent. In the case of the experiment carried out in this study, it does not seem to be a useful indicator of fat oxidation or sensory changes regarding aroma. Another component which was detected at a relatively high and similar level in fresh and stored meat samples without EOs added

was 2-pentylfuran. This compound could have appeared in meat due to lipid oxidation. It can also be an ingredient released by the heat of cooking, or by mechanical grinding, as took place in the case of the minced turkey meat assessed in the present study. Ercolini et al. (2010) also reported that 2-pentylfuran was produced by 54% of the 65 different strains of *Pseudomonas fragi* which were isolated by the authors from fresh and spoiled meat. Benzaldehyde and benzeneacetaldehyde are compounds that can be formed as a result of microbial spoilage (Casaburi et al., 2015). Benzeneacetaldehyde was detected by Ferrocino et al. (2013) in vacuum packed beef chops after storage at 1°C. In our studies this component was found only in stored control samples and samples containing caraway EO. Reduction of total viable count was not detected in samples with rosemary essential oil (Table 1). However, the absence of benzaldehyde and benzeneacetaldehyde in stored turkey meat with rosemary EO may evidence its influence on microbial metabolism or changes in qualitative composition of TVC. The addition of essential oils also reduced the concentration of hexathiane and cyclic octaatomic sulfur in stored samples. The significant presence of these components was detected by GC-MS-SPME in spoiled pork by Briones et al. (2017), who mentioned that these compounds are associated with the unpleasant odor in the samples of spoiled meat. However, it is difficult to assess the effect of EOs on the sensorially evaluated odor of the examined turkey meat since, for example, it is difficult to evaluate the contribution to the odor of those meat-derived compounds whose decrease in concentration was affected by these essential oils. The final effect of interactions between individual odor components depends on their and their mixture characteristics as well as the concentration of individual components. Different components have various odor thresholds, which can vary depending on the matrix of the food product in which they are detected (Ercolini et al., 2010). For example, based on the odor active value (OAV), Zhu et al. (2018) identified benzaldehyde and benzeneacetaldehyde as two of the components responsible for the chestnut-like aroma commonly attributed to an excellent-quality green tea. These ingredients have also been mentioned, for example, by Gu et al. (2013) as characteristic aroma-active compounds of some edible parts of steamed Chinese mitten crab (*Eriocheir sinensis*). The authors describe benzaldehyde as bitter and almond-like, while benzeneacetaldehyde was described as rosy and fruity. Benzaldehyde may result from catabolism of the aromatic amino acids and may be formed due to proteolytic activity of either microorganisms or meat's own enzymes (Ercolini et al., 2010). This substance was also detected by Soncin et al. (2007) in the raw breast meat of duck. Calkins and Hodgen (2007) list it among the compounds identified in beef. On the other hand, Freeman et al. (1976) reported that benzaldehyde was one of the components whose presence was associated with aerobic spoilage of chicken breasts and was only detected in the samples stored at 2°C, not in those kept at 10°C. The authors revealed that the temperature of meat storage affected the formation of some substances, e.g. benzaldehyde or 2-butanone in the aerobically stored samples, while others such as ethyl acetate occurred in both samples, stored at 2 and 10°C. The storage temperature of the raw material have an effect on the proliferation and metabolic activity of microorganisms. This study, however, showed that the applied EOs had no significant effect on the total microbial count, which probably mainly consist of lac-

tic acid bacteria (Table 1). At the same time, however, it cannot be excluded that microbiota changed qualitatively. Nevertheless, significant differences were found in the composition of volatile compounds (Table 4). The decrease in concentrations of some volatile compounds that occurred in the stored meat under the presence of essential oils could result from their influence on the composition of the microbiome, which did not significantly differ in total counts, microbial metabolism or chemical interaction, including anti- or prooxidative activity. Farag et al. (1989) also observed the antioxidant properties of both EOs; however, in comparison with essential oil of rosemary, EO of caraway exhibited stronger antioxidant properties, when applied to emulsified linoleic acid. Antioxidant activity of essential oils was reported to be derived partly from the presence of phenolic groups. Carvone, γ -terpinene and limonene are the components of caraway EO with strong antioxidant activity (Abou El-Soud et al., 2014), while eucalyptol, α -pinene and β -pinene are such components of rosemary EO (Wang et al., 2008). Santos et al. (2017) reported that as one of several essential oils, rosemary EO showed noticeable activity in terms of a bactericidal effect. However, according to the authors the effective concentrations of the examined EOs were too high to be used in food, as the odor was too intense. According to Seidler-Łożykowska et al. (2013) essential oil from caraway has medium antimicrobial properties. The smallest change in the pH value compared to fresh meat noted in the samples with a mixture of EOs also may indicate that despite the fact that essential oils had no effect on the count of microorganisms, their metabolic activity was to some extent limited (Table 2). The meat containing a mixture of oils also had the smallest increase in acid value (Table 2).

Conclusions

The use of essential oils in minced meat at sensorially acceptable concentrations (0.02%) had a positive effect on the reduction of fat rancidity as well as on the sensorially evaluated odor of the product. Compositional differences of the volatile compounds between the stored control sample and the samples with added EOs may indicate that sensory differences result not only from the masking effect of oil components, but also their impact on the formation of components of the odor of spoilage in meat. The applied additives had an insignificant effect on the total count of examined microorganisms and lactic acid bacteria count.

References

- Abou El-Soud N.H., El-Lithy N.A., El-Saeed G., Wahby M.S., Khalil M.Y., Morsy F., Shaffie N. (2014). Renoprotective effects of caraway (*Carum carvi* L.) essential oil in streptozotocin induced diabetic rats. *J. App. Pharm. Sci.*, 4: 27–33.
- Ahn D.U., Jo C., Olson D.G. (1999). Volatile profiles of raw and cooked turkey thigh as affected by purge temperature and holding time before purge. *J. Food Sci.*, 64: 230–233.
- Ahn D.U., Sell J.L., Jeffery M., Jo C., Chen X., Wu C., Lee J.I. (2006). Dietary vitamin E affects lipid oxidation and total volatiles of irradiated raw turkey meat. *J. Food Sci.*, 62: 954–958.
- AOCS (2004). Official methods and recommended practices of the AOCS. AOCS Press, Champaign.

- Argyri A.A., Mallouchos A., Panagou E.Z., Nychas G.-J.E. (2015). The dynamics of the HS/SPME-GC/MS as a tool to assess the spoilage of minced beef stored under different packaging and temperature conditions. *Int. J. Food Microbiol.*, 193: 51–58.
- Boskovic M., Djordjevic J., Ivanovic J., Janjic J., Zdravkovic N., Glisic M., Glamoclija N., Baltic B., Djordjevic V., Baltic M. (2017). Inhibition of *Salmonella* by thyme essential oil and its effect on microbiological and sensory properties of minced pork meat packaged under vacuum and modified atmosphere. *Int. J. Food Microbiol.*, 258: 58–67.
- Bosse (née Danz) R., Wirth M., Gibis M., Schmidt H., Weiss J. (2017). Kinetics of volatile marker compounds during ripening of cured loins inoculated with *Staphylococcus carnosus*. *J. Sci. Food Agr.*, 79: 3050–3057.
- Briones J.C., Castillon G., Delmo M.P., Santos G.N.C. (2017). Magnetic-field-enhanced morphology of tin oxide nanomaterials for gas sensing applications. *J. Nanomater.*, 4396723.
- Bulut Ç., Altioek E., Bayraktar O., Ülkü S. (2009). Antioxidative and antimicrobial screening of 19 commercial essential oils in Turkey. *Acta Hort.*, 826: 111–116.
- Calkins C.R., Hodge J.M. (2007). A fresh look at meat flavor. *Meat Sci.*, 77 (1 Spec. Iss.): 63–80.
- Casaburi A., Piombino P., Nychas G.-J., Villani F., Ercolini D. (2015). Bacterial populations and the volatiles associated to meat spoilage. *Food Microbiol.*, 45 (PA): 83–102.
- Chouliara E., Karatapanis A., Savvaidis I.N., Kontominas M.G. (2007). Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, stored at 4°C. *Food Microbiol.*, 24: 607–617.
- Corral S., Salvador A., Flores M. (2013). Salt reduction in slow fermented sausages affects the generation of aroma active compounds. *Meat Sci.*, 93: 776–785.
- Costello P., Siebert T., Solomon M., Bartowsky E. (2013). Synthesis of fruity ethyl esters by acyl coenzyme A: alcohol acyltransferase and reverse esterase activities in *Oenococcus oeni* and *Lactobacillus plantarum*. *J. Appl. Microbiol.*, 114: 797–806.
- Descalzo A.M., Insani E.M., Biolatto A., Sancho A.M., García P.T., Pensel N.A., Josifovich J.A. (2005). Influence of pasture or grain-based diets supplemented with vitamin E on antioxidant/oxidative balance of Argentine beef. *Meat Sci.*, 70: 35–44.
- Ercolini D., Casaburi A., Nasi A., Ferrocino I., Di Monaco R., Ferranti P., Mauriello G., Villani F. (2010). Different molecular types of *Pseudomonas fragi* have the same overall behaviour as meat spoilers. *Int. J. Food Microbiol.*, 142: 120–131.
- Farag R.S., Badei A.Z.M.A., Hewedi F.M., El-Baroty G.S.A. (1989). Antioxidant activity of some spice essential oils on linoleic acid oxidation in aqueous media. *J. Am. Oil. Chem. Soc.*, 66: 792–799.
- Ferrocino I., La Stora A., Torrieri E., Musso S.S., Mauriello G., Villani F., Ercolini D. (2013). Antimicrobial packaging to retard the growth of spoilage bacteria and to reduce the release of volatile metabolites in meat stored under vacuum at 1°C. *J. Food Protect.*, 76: 52–58.
- Freeman L.R., Silverman G.J., Angelini P., Merritt Jr. C., Esselen W.B. (1976). Volatiles produced by microorganisms isolated from refrigerated chicken at spoilage. *Appl. Environ. Microb.*, 32: 222–231.
- Govaris A., Solomakos N., Pexara A., Chatzopoulou P.S. (2010). The antimicrobial effect of oregano essential oil, nisin and their combination against *Salmonella* Enteritidis in minced sheep meat during refrigerated storage. *Int. J. Food Microbiol.*, 137: 175–180.
- Gu S.-Q., Wang X.-C., Tao N.-P., Wu N. (2013). Characterization of volatile compounds in different edible parts of steamed Chinese mitten crab (*Eriocheir sinensis*). *Food Res. Int.*, 54: 81–92.
- Hoover D.G. (2000). Microorganisms and their products in the preservation of foods. In: The microbiological safety and quality of food, Lund B.M., Baird-Parker T.C., Gould G.W. (eds). Vol. I, Aspen Publishers, Inc. Gaithersburg, Maryland, pp. 254–255.
- Illikoud N., Rossero A., Chauvet R., Courcoux P., Pilet M.-F., Charrier T., Jaffrès E., Zagorec M. (2019). Genotypic and phenotypic characterization of the food spoilage bacterium *Brochothrix thermosphacta*. *Food Microbiol.*, 81: 22–31.
- Irkin R., Esmer O.K. (2010). Control of *Listeria monocytogenes* in ground chicken breast meat under aerobic, vacuum and modified atmosphere packaging conditions with or without the presence of bay essential oil at 4°C. *Food Sci. Technol. Res.*, 16: 285–290.

- MacLeod G., Coppock B.M. (1976). Volatile flavor components of beef boiled conventionally and by microwave radiation. *J. Agr. Food Chem.*, 24: 835–843.
- Montel M.C., Masson F., Talon R. (1998). Bacterial role in flavour development. *Meat Sci.*, 49 (Suppl.1): S111–S123.
- Nazer A.I., Kobilinsky A., Tholozan J.-L., Dubois-Brissonnet F. (2005). Combinations of food antimicrobials at low levels to inhibit the growth of *Salmonella* sv. Typhimurium: A synergistic effect? *Food Microbiol.*, 22: 391–398.
- Nieminen T.T., Dalgaard P., Björkroth J. (2016). Volatile organic compounds and *Photobacterium phosphoreum* associated with spoilage of modified-atmosphere-packaged raw pork. *Int. J. Food Microbiol.*, 218: 86–95.
- Nychas G.J., Dillon V.M., Board R.G. (1988). Glucose, the key substrate in the microbiological changes occurring in meat and certain meat products. *Biotechnol. Appl. Biochem.*, 10: 203–231.
- Olivares A., Dryahina K., Španěl P., Flores M. (2012). Rapid detection of lipid oxidation in beef muscle packed under modified atmosphere by measuring volatile organic compounds using SIFT-MS. *Food Chem.*, 135: 1801–1808.
- Othman A.L.Z.M., Yasser E.-H., Samy M.F., Ahmed G.M. (2016). Antioxidative and antimicrobial properties of essential oil of certain aromatic plants. *Res. J. Pharm. Biol. Chem. Sci.*, 7: 1943–1951.
- Oz F., Yuzer M.O. (2017). The effects of different cooking methods on the formation of heterocyclic aromatic amines in turkey meat. *J. Food Process. Pres.*, 41: e13196.
- Pin C., García de Fernando G.D., Ordóñez J.A. (2002). Effect of modified atmosphere composition on the metabolism of glucose by *Brochothrix thermosphacta*. *Appl. Environ. Microb.*, 68: 4441–4447.
- Pothakos V., Devlieghere F., Villani F., Björkroth J., Ercolini D. (2015). Lactic acid bacteria and their controversial role in fresh meat spoilage. *Meat Sci.*, 109: 66–74.
- Santos M.I.S., Martins S.R., Veríssimo C.S.C., Nunes M.J.C., Lima A.I.G., Ferreira R.M.S.B., Pedros L., Sousa I., Ferreira M.A.S.S. (2017). Essential oils as antibacterial agents against food-borne pathogens: Are they really as useful as they are claimed to be? *J. Food Sci. Tech.*, 54: 4344–4352.
- Seidler-Łożykowska K., Kędzia B., Karpińska E., Bocianowski J. (2013). Microbiological activity of caraway (*Carum carvi* L.) essential oil obtained from different origin. *Acta Sci. Agron.*, 35: 495–500.
- Shahbazi Y., Karami N., Shavisi N. (2018). Effect of *Mentha spicata* essential oil on chemical, microbial, and sensory properties of minced camel meat during refrigerated storage. *J. Food Safety*, 38: e12375.
- Shahidi F., Pegg R.B. (1994). Hexanal as an indicator of meat flavor deterioration. *J. Food Lipids*, 1: 177–186.
- Silva-Flores P.G., Pérez-López L.A., Rivas-Galindo V.M., Paniagua-Vega D., Galindo-Rodríguez S.A., Álvarez-Román R. (2019). Simultaneous GC-FID Quantification of main components of *Rosmarinus officinalis* L. and *Lavandula dentata* essential oils in polymeric nanocapsules for antioxidant application. *J. Anal. Methods Chem.*, 2837406: 9 pp.
- Skandamis P.N., Nychas G.-J.E. (2001). Effect of oregano essential oil on microbiological and physico-chemical attributes of minced meat stored in air and modified atmospheres. *J. Appl. Microbiol.*, 91: 1011–1022.
- Soncin S., Chiesa L.M., Cantoni C., Biondi P.A. (2007). Preliminary study of the volatile fraction in the raw meat of pork, duck and goose. *J. Food Compos. Anal.*, 20: 436–439.
- Van Ba H., Amna T., Hwang I. (2013). Significant influence of particular unsaturated fatty acids and pH on the volatile compounds in meat-like model systems. *Meat Sci.*, 94: 480–488.
- Vasilatos G.C., Savvaidis I.N. (2013). Chitosan or rosemary oil treatments, singly or combined to increase turkey meat shelf-life. *Int. J. Food Microbiol.*, 166: 54–58.
- Wang W., Wu N., Zu Y.G., Fu Y.J. (2008). Antioxidative activity of *Rosmarinus officinalis* L. essential oil compared to its main components. *Food Chem.*, 108: 1019–1022.
- Wong M.K., Sampugna J., Dickey L.E. (1993). Moisture, total lipid, fatty acids, and cholesterol in raw ground turkey. *J. Agr. Food Chem.*, 41: 1229–1231.

- Yang C., Qi Y., Zheng J., Fan X., Liang P., Song C. (2018). Efficacy of various preservatives on extending shelf life of vacuum-packaged raw pork during 4°C storage. *J. Food Protect.*, 81: 636–645.
- Yano Y., Maeda T., Hirata T. (1995). The headspace volatiles generated at the initial stage of spoilage in the aerobically and vacuum packed beef, pork and chicken. *Anim. Sci. Technol. (Jpn.)*, 66: 684–692.
- Ying W., Ya-Ting J., Jin-Xuan C., Yin-Ji C., Yang-Ying S., Xiao-Qun Z., Dao-Dong P., Rong-Chang O., Ning G. (2016). Study on lipolysis-oxidation and volatile flavour compounds of dry-cured goose with different curing salt content during production. *Food Chem.*, 190: 33–40.
- Zhu Y., Lv H.-P., Shao C.-Y., Kang S., Zhang Y., Guo L., Dai W.-D., Tan J.-F., Peng Q.-H., Lin Z. (2018). Identification of key odorants responsible for chestnut-like aroma quality of green teas. *Food Res. Int.*, 108: 74–82.

Received: 26 VIII 2020

Accepted: 15 X 2020