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DETERMINATION AND CLASSIFICATION OF VOLATILE COMPOUNDS OF PASTIRMA USING SOLID PHASE MICROEXTRACTION/GAS CHROMATOGRAPHY/MASS SPECTROMETRY

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ABSTRACT

Pastırma, a traditional dry cured Turkish meat product, has a great number of specific aroma compounds, which occur as a result of lipid oxidation, protein degradation and formulation of *çemen* paste. These compounds give characteristic flavor to pastırma and the main objective of this study was to determine the nature of these compounds. Fifty-eight volatile compounds, grouped into nine chemical classes were identified using solid phase microextraction technique (SPME) coupled to gas chromatography/mass spectrometry (GC-MS). Aldehydes, mostly lipid oxidation products, were determined as the major chemical group, representing 17.54-78.02% of total volatile compounds. The major volatile aldehyde was hexanal (2.36-55.41%), followed by 2-methyl-2-butenal (0.97-14.69%) and then heptanal (0.29-4.77%). Sulfur compounds possibly derived from spices or formed by proteolysis of sulfur-containing amino acids, were the second most abundant group, with concentrations ranging between 6.04 and 50.60%. Other important volatile compounds of pastırma were aliphatic hydrocarbons, aromatic ketones, hydrocarbons, esters, alcohols, acids, terpenes, and furans.

Keywords: Aroma, dry cured meat products, GC-MS, hexanal, meat flavor, SPME, volatile compounds

INTRODUCTION

Pastırma which is a traditional dry-cured, non-fermented Turkish raw meat product is listed under the group of intermediate moisture foods. Its name "pastırma" is derived from the Turkish verb "bastırma" which means pressing (**Aksuksu *et al.*, 2005a**; **Gök *et al.*, 2008**; **Kilic, 2009**). It is produced from whole beef or water buffalo muscles obtained from 21 different parts of the carcass, defined in the Turkish standard for pastırma (**TS 1071, 2002**). However, sırt (*M.cutaneous maximus, M.trapezius dorsi, M.latissimus dorsi, M.longissimus dorsi*), kuşgömü (*M.psoas major, M.psoas minor, M.sartorius, M.iliopsoas*) and antrikot (*M.longissimus thoracis*) are generally used for the production of pastırma in Turkey.

First in pastırma production, muscles obtained during the onset of rigor mortis are left to rest at room temperature until the pH decreases to 5.8-6.0. Then, visible fat and connective tissue are removed and the meats are dry-cured using a mixture of salt and nitrite/nitrate. This mixture is rubbed on one side of the meat and meat blocks are stacked up to create pressing effect. They were led to rest for one day to allow penetration of curing materials to meat block. The next day, the other side of meat is rubbed with curing mixture and the meat blocks are stacked up again. Thereafter, the meats are rinsed with water to remove excess salt and left to air-dry for approximately 10 days. After the completion of drying process, the meats are covered with a 0.3 to 0.5 cm thick layer of *çemen* paste prepared from a mixture of fenugreek flour, ground garlic and red pepper using water. Finally, the meats are dried again for 1 or 2 days to obtain the final product. This process takes approximately one month, depending on the moisture content of final product, size of meats and process conditions. Moisture content should be lower than 50% according to the Turkish standard (**TS 1071, 2002**). Non-sliced pastırma can be stored without refrigeration for approximately nine months. However, sliced pastırma should be packed and stored at 4°C (**Kaban, 2005**; **Kilic, 2009**).

Pastırma is a popular dry-cured raw meat product among all kind of meat products in Turkey, because it has a characteristic flavor which is spicy and aromatic. This flavor occurs throughout ripening period of pastırma as a result of three basic factors: *çemen* paste, lipid oxidation, and proteolysis. *Çemen* paste is the most effective factor for improving the flavor of pastırma. In addition, it protects pastırma against microbial growth and oxygen penetration and facilitates the formation of desirable color, appearance, taste and texture (**Aksu *et al.*, 2005a**; **Gök *et al.*, 2008**). The other important factor, lipid oxidation and proteolysis, are responsible for the formation of volatile compounds that affect the flavor of pastırma (**Kaban, 2005**).

Historically, pastırma was produced and consumed in the Kayseri and Afyon regions of Turkey because these regions were very suitable areas for the breeding of beef cattle and water buffalo. Currently, production of pastırma is possible in most parts of Turkey. However, the traditional high-quality Turkish pastırma is still produced in Kayseri and Afyon regions. In the scientific literature, there are great numbers of research regarding chemical, physical and microbiological properties of pastırma collected from retail market (**Özdemir *et al.*, 1999**; **Aksu and Kaya, 2001**); changes in physicochemical, microbiological parameters and volatile compounds of pastırma during processing (**Kaban, 2009**); utilization of starter cultures and different curing materials in the production of pastırma (**Aksu and Kaya, 2002a,b,c**; **Dogruer *et al.*, 2003**); effects of packing method, storage time and temperature on the quality of pastırma (**Aksu *et al.*, 2005a,b**; **Gök *et al.*, 2008**), but there is no scientific data on the volatile compounds profile of traditional pastırma.

Considering all the above cited information, the aim of present study was to determine and classify the volatile compounds of traditional Turkish pastırma produced from different type of beef muscles and obtained from the Kayseri and Afyon regions of Turkey.

MATERIAL AND METHODS

Samples

Sixteen brands of sliced pastırma were purchased from seven leading companies in Kayseri and Afyon. These were produced from four different parts of the carcass "1) Antrikot: *M. longissimus thoracis* 2) Kuşgömü: *M. psoas major, M. psoas minor, M. sartorius, M. iliopsoas* 3) Sırt: *M. cutaneous maximus, M. trapezius dorsi, M. latissimus dorsi, M. longissimus dorsi* 4) Eğrice: *M. gracilis, M. adductor, M. pectineus"*. The experimental design is shown in Table 1. The samples were immediately transferred to the laboratory in a vacuum package and the volatile compound analysis was immediately performed. Each sample was analyzed in duplicate.

Table 1 Experimental design.

Companies	The name of meat (part of carcass) used pastırma production†	Sample Number
A	Antrikot	A1
	Bonfile	A2
	Sırt	A3
B	Antrikot	B1
	Kuşgömü	B2
	Sırt	B3
C	Antrikot	C1
	Eğrice	C2
	Sırt	C3
D	Antrikot	D1
	Kuşgömü	D2
	Sırt	D3
E	Sırt	E1
F	Sırt	F1
G	Antrikot	G1
	Sırt	G2

†Antrikot: *M. longissimus thoracis*
Sırt: *M. cutaneous maximus, M. trapezius dorsi, M. latissimus dorsi, M. longissimus dorsi*
Kuşgömü: *M. psoas major, M. psoas minor, M. sartorius, M. iliopsoas*
Eğrice: *M. gracilis, M. adductor, M. pectineus*

Volatile Compounds

Six slices pastırma selected randomly from one package were minced using knife and approximately 3 g of the minced sample was inserted into a 20 mL headspace screw top vial and allowed to equilibrate for 30 min at 35 ºC. The headspace of the samples was extracted for 90 min at 35 ºC using a CTC Combi PAL auto sampler equipped with 75 µm carboxen/polydimethylsiloxane (CAR/PDMS) solid phase micro extraction (SPME) fiber. The volatile compounds were desorbed by directly inserting the fiber for 10 min into the injection port of the gas chromatograph (GC) maintained at 250 ºC.
Analysis of volatile compounds was performed using an Agilent model 7890 Series gas chromatograph coupled to CTC Combi PAL auto-sampler and an Agilent 5975 N mass selective detector. The compounds were separated in a DB-624 (J&W Scientific, 30 m, 0.25 mm i.d., 1.4 µm film thickness), working with the following temperature programme: 40 ºC, hold for 5 min; 3 ºC min^{-1} up to 110 ºC; 4 ºC min^{-1} up to 150 ºC; 10 ºC min^{-1} up to 210 ºC, hold for 12 min. The temperatures for the injection port, ion source, quadrupole and interface were set at 250, 230, 150 and 240 ºC, respectively. Mass spectra were obtained in the electron impact at 70 eV in full scan and a scan range from m/z 41-400. Identification of the constituents was based on: (i) a comparison of the retention times with those of authentic reference compounds, (ii) their retention indexes relative to a series of *n*-hydrocarbons (C4-C20), and (iii) computer matching against NIST and Wiley library mass spectra.

RESULTS AND DISCUSSION

In total, 58 volatile compounds were identified in the 16 samples under study (Table 2). These compounds can be divided into 9 chemical families: aldehydes (14 compounds), hydrocarbons (7), sulfur compounds (8), terpenes (7), esters (7), acids (5), alcohols (3), ketones (3), and furans (1). In general, the results of the present study agreed with those of **Kaban (2005),** who examined the changes in the composition of volatile compounds during pastırma processing. However, some differences were observed and could be linked with different raw meats used in pastırma production and different processing conditions (**Kaban, 2005**).
Aldehydes were the major chemical group, representing 17.5-78.0% of total volatile compounds. From the 14 aldehydes, the main one was hexanal (2.36-55.4%), followed by 2-methyl-2-butenal (0.97-14.7%). **Stahnke (1994)** conducted a research on a fermented dried sausage and reported that a high number of aldehydes are formed by lipid oxidation of unsaturated fatty acids. Also, hexanal comes from linoleic acid oxidative decomposition and imparts a green odor, which is considered a distinctive characteristic of these products. In the current study, 2-methyl-2-butenal content ranged between 0.97 and 14.7%. **Calvo-Gomez *et al.* (2004)** reported that 2-methyl-2-butenal was found in essential oil of garlic, suggesting that the compound present in the pastırma samples originated from the garlic used in the preparation of the *çemen*. This compound was found to be abundant in some brands of pastırma, especially A1, A2, A3 and the amount varied according to the different formulation used by the producers. The lipid oxidation products: pentanal, heptanal, *cis*-2-hexenal, heptenal, octanal, *trans*-2-octenal, and *cis*-2-decenal, were found at concentrations lower than 2%, except pentanal, heptanal and *cis*-2-hexenal. Of these, *trans*-2-octenal contributed to the smell and flavor of meat (**Calkins and Hodgen, 2007**). American dry-cured ham, which has a similar production process with pastırma, was characterized by benzaldehyde, which contributes to cooked and burnt flavor (**Pham *et al.*, 2008**). Although pastırma is uncooked meat product, benzaldehyde was detected at low levels in some pastırma samples but not in others. In addition, phenylacetaldehyde, at concentrations lower than 1%, was found in samples A1, E1, F1, G1, and G2. **Carrapiso *et al.*, (2010)** found phenylacetaldehyde in spoiled Iberian hams and described its odor as flowery, solvent-like and fruity. In another study, benzaldehyde and phenylacetaldehyde were found in roasted pork meat (**Xie *et al.*, 2008**).
In the current study, 8 sulfur compounds were identified, and they were the second most abundant chemical group, after aldehydes, on the volatile profile of pastırma. These compounds ranged between 6.04 and 50.6%. Diallyl disulfide was the volatile compound that showed the greatest variability among brands, ranging from 3.12 to 31.6% of the total area. Diallyl sulfide and methyl allyl disulfide were also found at high concentrations, ranging from 0.64-13.6% and 0.96-6.85%, respectively. Most of the samples were rich in dimethyl trisulfide, with the lowest and highest contents been found in samples A1 and F1 (13.2%), respectively. However, allyl methyl sulfide content was lower in all samples except G1 (5.14%). Other sulfur compounds (3-methylthio propanal, propenyl methyl disulfide and methyl allyl trisulfide) were found at low concentration or even not detected. Sulfur compounds are of great importance in the flavor of meat products because of their low odor thresholds (**Ramarathnam, 1998**). The presence of these compounds only in the final product was reported by **Kaban (2009)**. Most of these sulfur compounds are thought to come from spices used in pastırma processing, especially from garlic (**Ramirez and Cava, 2007**). In addition, sulfide compounds are formed by proteolysis of sulfur-containing amino acids (**Ramarathnam, 1998**; **Sabio *et al.*, 1998**).

Table 2 Area percentage relative to the total peak area of the identified peaks of volatile compounds detected from traditional Turkish pastırma

Compound (Retention Index)	BRANDS															
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	F1	G1	G2
ALDEHYDES																
Pentanal (737)	2.17	2.45	0.71	2.48	1.32	0.92	1.42	2.06	1.62	2.17	1.60	1.62	2.32	1.57	0.68	0.69
2-Metil-2-butenal (789)	14.69	10.61	11.76	6.42	3.72	4.87	3.17	4.17	4.32	6.25	5.56	4.83	2.83	0.97	2.10	2.42
Hexanal (841)	22.25	55.15	2.36	48.31	55.41	44.81	37.24	46.82	42.59	39.98	50.03	31.45	38.77	47.07	20.71	31.92
cis-2-Hexenal (909)	2.60	1.63	1.19	0.50	1.54	1.47	1.55	0.71	2.36	0.60	1.00	0.83	0.77	1.25	0.95	1.14
Heptanal (945)	1.03	4.77	0.29	1.53	0.97	1.62	1.31	2.91	2.02	2.76	1.12	1.59	1.84	1.40	0.77	0.51
2-Heptenal (1016)	0.69	0.76	nd	0.42	0.45	0.40	0.43	0.24	0.73	0.37	0.32	0.45	0.21	0.21	0.24	0.68
Benzaldehyde (1026)	nd†	nd	nd	0.54	0.28	1.35	1.01	0.82	1.13	nd	nd	0.75	nd	nd	nd	nd
Octanal (1045)	0.28	0.53	0.56	nd	0.12	0.13	0.19	0.14	0.18	nd	nd	nd	0.08	nd	0.10	nd
2,4-Heptadienal (1072)	nd	nd	nd	nd	nd	nd	0.12	nd	nd	nd	0.07	nd	0.16	0.22	nd	nd
Phenylacetaldehyde (1102)	0.11	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.27	0.09	0.11	0.13
trans-2-octenal (1118)	0.33	0.14	nd	nd	0.10	0.11	nd	nd	nd	nd	0.09	0.11	nd	0.20	0.93	0.07
Nonanal (1156)	1.60	1.99	0.66	0.75	0.88	1.73	1.01	1.19	1.19	1.78	1.12	1.43	1.22	1.09	1.05	0.70

cis-2-Nonenal (1223)	nd	nd	nd	nd	nd	nd	0.05	nd	nd	nd	nd	nd	0.12	0.11	nd	0.09
cis-2-Decenal (1326)	0.14	nd	nd	nd	0.09	0.10	0.14	0.09	0.19	nd	0.08	0.12	0.29	0.14	0.15	0.43
Subtotal	**45.91**	**78.02**	**17.54**	**60.95**	**64.86**	**57.49**	**47.64**	**59.15**	**56.33**	**53.91**	**60.99**	**43.18**	**48.88**	**54.31**	**27.79**	**38.78**
SULPHUR COMPOUNDS																
Allyl methyl sulfide (717)	0.85	nd	0.94	0.41	0.19	0.24	0.98	1.05	0.49	0.90	0.15	0.63	1.22	2.38	5.14	0.60
Diallyl sulphide (886)	2.07	0.64	2.75	2.06	1.91	1.67	1.74	1.82	1.72	2.20	1.10	2.81	3.31	4.61	13.55	3.76
Methyl allyl disulfide (956)	6.18	0.96	6.85	3.38	2.64	2.29	4.00	4.05	4.46	5.63	2.16	5.22	2.91	2.07	5.45	4.46
3-Methylthio propanal (961)	1.48	0.71	2.39	nd	nd	nd	nd	nd	nd	nd	0.21	0.14	0.12	nd	nd	0.05
Propenyl methyl disulfide (977)	0.35	0.13	0.32	0.26	0.35	0.26	0.24	0.21	0.25	0.17	0.09	0.17	nd	nd	nd	0.39
Dimethyltrisulfide (998)	nd	0.48	0.24	8.43	2.95	2.55	9.49	7.12	5.71	8.09	7.44	5.19	11.09	13.19	2.72	0.06
Diallyl disulfide (1130)	11.16	3.12	14.48	9.79	13.86	14.64	11.52	8.44	13.82	11.68	9.86	27.57	11.08	6.29	23.55	31.58
Methyl allyl trisulfide (1194)	0.26	nd	nd	0.14	0.16	3.87	nd	0.20	0.37	0.10	0.07	0.07	0.26	0.07	0.19	0.78
Subtotal	**22.35**	**6.04**	**27.97**	**24.48**	**22.06**	**25.51**	**27.97**	**22.90**	**26.80**	**28.77**	**21.08**	**41.80**	**29.99**	**28.61**	**50.60**	**41.69**
KETONES																
3-hydroxy-2-butanone	8.88	nd	21.89	0.64	nd	1.74	nd	0.50	nd	2.18	0.16	0.11	nd	0.22	nd	nd
2-heptanone	0.66	0.34	2.72	0.28	0.14	0.28	0.17	0.27	0.12	0.44	0.41	0.39	0.25	0.22	0.06	nd
2-octanone	nd	nd	0.27	0.33	nd	0.16	0.14	nd	0.12	0.64	0.73	0.52	0.94	1.53	0.33	nd
Subtotal	**9.54**	**0.34**	**24.87**	**1.25**	**0.14**	**2.17**	**0.32**	**0.77**	**0.24**	**3.25**	**1.30**	**1.02**	**1.19**	**1.96**	**0.39**	**nd**
HYDROCARBONS																
octane	3.59	1.29	3.62	1.33	0.74	1.00	1.14	3.76	0.93	3.53	1.00	0.87	0.80	4.05	9.86	nd
p-xylene	nd	0.49	1.01	0.63	0.39	0.40	0.21	0.21	0.20	nd	nd	0.07	0.14	nd	nd	nd
nonane	nd	nd	nd	nd	nd	nd	0.23	nd	0.15	nd	nd	nd	nd	nd	0.26	nd
undecane	nd	0.11	0.26	nd	nd	0.12	8.22	4.78	3.92	nd	0.17	nd	nd	nd	nd	nd
dodecane	0.15	0.11	0.20	nd	nd	nd	2.68	1.34	1.24	nd	nd	nd	nd	nd	nd	nd
tridecane	0.20	0.19	0.22	nd	nd	nd	0.51	0.24	0.27	nd	nd	nd	nd	nd	nd	0.11
tetradecane	0.42	0.20	0.29	nd	0.05	0.06	nd	nd	nd	nd	nd	nd	nd	0.18	nd	0.04
Subtotal	**4.36**	**2.38**	**5.60**	**1.96**	**1.19**	**1.58**	**13.00**	**10.33**	**6.73**	**3.53**	**1.17**	**0.94**	**0.94**	**4.23**	**10.12**	**0.15**

Compound (Retention Index)	**BRANDS**															
	A1	**A2**	**A3**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E1**	**F1**	**G1**	**G2**
ESTERS																
methyl-3-methylbutanoate	nd	0.24	nd	nd	nd	nd	0.17	nd	0.25	nd	nd	0.13	nd	0.32	nd	nd
ethyl-2-methylbutanoate	nd	nd	0.58	nd	nd	nd	nd	0.21	nd	nd	0.08	nd	0.08	nd	0.17	nd
methyl-2,4-hexadienoate	1.67	0.87	1.24	0.57	0.81	1.96	0.97	0.81	1.05	1.47	4.04	2.16	4.68	nd	0.65	2.63
methyl-2,4-hexadienoate	2.91	1.44	5.08	1.32	1.08	1.75	0.48	0.33	0.42	1.68	1.76	0.84	0.66	1.05	0.56	0.23
metil allil thioacetate	0.86	0.27	0.90	1.09	2.64	2.43	0.78	0.63	0.89	0.56	0.67	1.30	0.56	0.11	0.55	3.70
ethyl octanoate	0.49	0.46	nd	0.20	0.32	0.34	0.30	0.12	0.27	0.20	0.07	0.29	0.17	0.39	0.14	0.60
methyl nonanate	0.14	0.14	0.26	0.07	0.10	0.13	0.13	0.06	0.11	0.06	0.06	0.09	0.06	0.06	0.08	0.06
Subtotal	**6.07**	**3.42**	**8.05**	**3.25**	**4.96**	**6.61**	**2.82**	**2.16**	**2.98**	**3.97**	**6.68**	**4.81**	**6.22**	**1.93**	**2.15**	**7.23**
ALCOHOLS																
4-hexen-1-ol	0.65	nd	2.94	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.10	nd	0.20	nd
1-octen-3-ol	nd	nd	nd	nd	nd	nd	0.17	0.07	0.10	nd	0.06	nd	0.09	nd	nd	nd
1-octanol	nd	0.60	nd	0.25	0.27	0.32	0.30	0.15	0.46	0.29	0.34	0.44	0.23	0.17	0.15	0.34
Subtotal	**0.65**	**0.60**	**2.94**	**0.25**	**0.27**	**0.32**	**0.47**	**0.22**	**0.56**	**0.29**	**0.41**	**0.44**	**0.42**	**0.17**	**0.35**	**0.34**
ACIDS																
hexanoic acid	nd	0.23	nd	nd	0.16	0.12	0.13	nd	0.17	nd	0.07	0.10	0.09	nd	nd	0.17
3-methyl butanoic acid	nd	nd	nd	nd	nd	nd	0.42	0.49	0.32	0.11	nd	0.12	0.19	0.26	0.30	nd
2-methyl butanoic acid	nd	nd	nd	nd	nd	nd	0.20	0.22	0.13	nd	0.07	0.04	0.09	0.13	nd	nd
2,4-hexadienoic acid (E, E)	1.90	nd	1.98	3.87	1.37	nd	nd	nd	nd	0.25	0.45	0.45	nd	nd	nd	0.10
octanoic acid	nd	nd	nd	nd	0.13	0.10	nd	nd	nd	nd	nd	0.15	0.17	nd	0.12	0.50
Subtotal	**1.90**	**0.23**	**1.98**	**3.87**	**1.67**	**0.22**	**0.75**	**0.71**	**0.62**	**0.36**	**0.59**	**0.85**	**0.54**	**0.39**	**0.41**	**0.77**
TERPENES																
sabinene	nd	0.41	0.35	nd	nd	nd	0.57	0.47	0.38	nd	nd	0.08	0.38	0.26	nd	nd

myrcene	nd	0.29	0.27	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.10	nd	nd	0.07
alpha-terphinene	1.99	2.66	1.44	0.75	0.59	nd	nd	nd	nd	0.57	2.45	0.40	2.69	1.67	1.38	0.73
limonen	1.27	2.53	0.75	1.15	0.85	1.42	0.87	1.25	1.42	2.06	1.40	1.53	3.78	2.41	1.14	0.97
p-cymene	0.69	0.70	1.17	0.46	0.78	0.96	0.70	0.46	0.80	0.40	0.62	0.68	2.64	1.68	3.85	3.79
gamma-terpinene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.08	nd	0.26	0.09
β-caryophyllene	0.29	nd	0.18	nd	0.08	nd	nd	nd	nd	nd	nd	0.12	0.06	nd	nd	0.34
Subtotal	**4.24**	**6.58**	**4.17**	**2.36**	**2.30**	**2.38**	**2.13**	**2.18**	**2.60**	**3.03**	**4.46**	**2.81**	**9.73**	**6.02**	**6.64**	**5.99**
FURANS																
2-penthyl furan	0.46	0.36	0.82	0.36	0.40	0.76	0.23	0.25	0.24	0.49	0.60	0.61	0.49	0.36	0.24	0.26
Subtotal	**0.46**	**0.36**	**0.82**	**0.36**	**0.40**	**0.76**	**0.23**	**0.25**	**0.24**	**0.49**	**0.60**	**0.61**	**0.49**	**0.36**	**0.24**	**0.26**

[†]*nd= not detected.*

Three ketones (3-hyrdoxy-2-butanone, 2-heptanone and 2-octanone), were identified in the current study. Of these, 3-hydroxy-2-butanone, which was described as dull breath broth by **Shahidi *et al.* (1986)**, was found at highest concentration in two samples: A1 (8.88%) and A3 (21.9%). This compound is related to the non-enzymatic browning reaction of lactose-casein model systems and fructose degradation (**El-Magoli *et al.*, 1996**). 2-heptanone, an oxidation product of linoleic acid (**Flores *et al.*, 1997**) was found at low concentrations in pastırma samples except A3.

In total, 7 hydrocarbons were identified in pastırma. Octane and undecane were found at levels up to 9.86% and 8.22%, respectively. Aliphatic hydrocarbons are secondary oxidation products from lipid oxidation and do not generally contribute to meat flavor because of their high flavor thresholds (**Ramarathnam, 1998**; **Ramirez and Cava, 2007**). However, aromatic hydrocarbons have different characteristics, such as *p*-xylene, which gives fruity odors (**Ramarathnam, 1998**).

The most abundant esters extracted by SPME were methyl-2,4-hexadienoate and methyl allyl thioacetate. Methyl-2,4-hexadienoate content reached approximately 6% in pastırma samples. Previous studies (**Mateo and Zumalacarregui, 1996)** reported that these compounds were also found in chorizo, a typical Spanish dry fermented sausage. Methyl allyl thioacetate was between 0.11-3.70% in the present study. The other identified esters were methyl-3-methylbutanoate, ethyl-2-methylbutanoate, ethyl octanoate and methyl nonanate. Esters, which may have originated from alcohols and acids as a result of microbial activity (**Mateo and Zumalacarregui, 1996**; **Sabio *et al.*, 1998)** have low odor thresholds in dry fermented sausages and contribute to the aroma with fruity and sweet notes (**Stahnke, 1994**). Esters have also been identified in other dry-cured meat products, such as: Bayonne and Corsican hams (traditional French hams), Iberian and Serrano hams (traditional Spanish hams), and Parma and Light Italian Country hams (traditional Italian hams) (**Sabio *et al.*, 1998**; **Ruiz *et al.*, 1999**; **Muriel *et al.*, 2004**; **Ramirez and Cava, 2007**).

The percentages of alcohols ranged from 0.17 to 2.94%. A high level of 4-hexen-1-ol was only found in sample A3 (2.94%). In another study by **Olivares *et al.* (2011)**, 4-hexen-1-ol was also detected in dry fermented sausages. The other alcohols were found at levels below 1% in the present study. Alcohols are crucial components of dry-cured raw meat products due to their low odor threshold (**Sabio *et al.*, 1998**). The alcohols identified in the current research were also reported by other researchers (**Ramirez and Cava, 2007**; **Muriel *et al.*, 2004**; **Garcia-Esteban *et al.*, 2004**).

The acid content of Turkish pastırma ranged between 0.22 and 3.87%, of which *trans-trans*-2,4-hexadienoic acid was the major compound. It was identified in six samples, at concentrations up to 3.87%, whereas it was not found in the other eight brands. *trans-trans*-2,4-Hexadienoic acid is used as an antimicrobial agent to prevent mold, yeast and fungi (**Cassens, 1998**). Hexanoic acid, 3-methylbutanoic acid, 2-methylbutanoic acid and actinic acid were the other acids identified among volatile compounds of the samples and were lower than 0.6%. In general, lower concentration of acids were observed in pastırma samples and could be linked with carbohydrate metabolism, lipolysis, and amino acid catabolism (**Mateo and Zumalacarregui, 1996),** which are the basic phenomenon occur during pastırma processing and affect characteristic flavor and texture of the final product.

Seven terpenes were identified, and their contents ranged between 2.13 and 6.64% of the total area. α-terpinene, limonene and *p*-cymene were found at different percentages and at higher levels than sabinene, myrcene, γ-terpinene and β-caryophyllene. Percentages of these terpenes were up to 2.69, 3.78 and 3.85%, respectively. These compounds are related to the use of spices in the preparation of pastırma, particularly fenugreek and red pepper (**Ramirez and Cava, 2007**). They impart sensory properties to pastırma, such as spicy flavor as well as fruity, floral, and fresh notes.

Among the furans, only 2-pentylfuran was detected (0.23-0.82%). In previous research, 2-pentylfuran was found in cooked pork as an oxidation product of linoleic acid and gave meaty aromas, such as ham-like aroma in Spanish Serrano dry-cured ham (**Flores *et al.*, 1997**). Although pastırma is an uncooked meat product, 2-pentylfuran was determined in the samples due to possible result of linoleic acid oxidation.

CONCLUSION

Pastırma, a traditional Turkish dry-cured, uncooked raw meat product, has a unique flavor profile. The volatile compounds of pastırma consisted of aldehydes, hydrocarbons, sulfur compounds, terpenes, esters, acids, alcohols, ketones, and furans. These compounds varied among brands due to differences in the processing conditions and type and amount of ingredients used in the pastırma processing. In particular, aldehydes and sulfur compounds were the major volatile groups of pastırma; their concentrations varied depending on the brands. All volatile compounds of pastırma in each of the chemical groups contributed to the product's pleasant aroma. These volatile compounds appeared to be mainly produced by lipid oxidation as well as coming from the spices used in the preparation of the *çemen* paste. Most of the sulfur compounds were likely to derive from garlic. Terpenes were other chemical group contributing to the aroma of pastırma and led to improve spicy flavor that possibly came from red pepper and fenugreek used in *çemen* paste. In summary, it can be concluded that nine basic chemical groups affect characteristic flavor of Turkish pastırma. In addition, type and concentration of volatile compounds under these chemical groups differ according to the processing conditions and source and amount of meat and other ingredients used in the pastırma production.

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