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The Effect of Roasting on Volatile Compounds of Ground Coffee and Turkish Coffee Brew

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A R T I C L E I N F O

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A B S T R A C T

Roasting is the most important coffee processing stage that affects coffee flavour. Coffee brew is prepared by various methods and Turkish coffee brewing technique is one of the oldest methods among other coffee preparation techniques. In this study, volatile compounds of light, medium, dark roasted ground coffee and Turkish coffee brews prepared from light, medium, dark roasted coffees were evaluated and the effect of roasting process was determined. The volatile compounds from acid (2), alcohol (1), aldehyde (2), furan (8), furanone (3), ketone (1), lactone (1), phenol (3), pyrazine (19), pyridine (1), pyrrole (6), and thiophene (1) chemical group was detected in all roasted ground coffee samples. However, volatiles compounds from acid, alcohol and furanone group were not detected in any Turkish coffee brew. Pyrazines were main volatile compounds of light roasted ground coffee and Turkish coffee brew of light roasted coffee. On the other hand, furans were main volatile compounds of medium, dark roasted ground coffee and Turkish coffee brew prepared from medium, dark roasted coffees followed by pyrazines.

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Introduction

Coffee is widely consumed worldwide and contains more than 800 volatile compounds from acids, alcohols, aldehydes, esters, furan, ketones, lactones, phenols, pyrazines pyridines, pyrroles, and sulphur compounds chemical groups (Brohan et al., 2009; Madihah et al., 2013; de Melo Pereira et al., 2019). The chemical composition of the green coffee bean, as well as the changes that occur with the post-harvest processes, affect the coffee quality (Bhumiratana et al., 2011; Sunarharum et al., 2014).

Roasting is the most important stage of coffee production in order to generate the desired, pleasant aroma and flavour of the coffee (Makri et al., 2011). The composition of roasted coffee depends on the roasting conditions. Chemical reactions during roasting result in several changes in chemical composition as well as aroma and flavour of coffee (Agresti et al., 2008). Coffee volatile compounds which affect coffee quality form with reactions taking place during roasting process namely caramelization, Maillard reaction, Strecker degradation, breakdown of amino acids (Makri et al., 2011; Lee et al., 2017). Roasted coffee is defined in three categories as light, medium, and high roasted depending on the degree of roasting (Franca et al., 2009).

Coffee brew preparation is an extraction technique and changes depending on geographic, cultural, and social structure. Generally, three main extraction technique is used for coffee brewing such as decoction, infusion, and pressure methods. The decoction method is one of the oldest coffee brewing methods (Cordoba et al., 2020). Turkish coffee brew is prepared according to decoction method. Roasted and fine ground coffee is heated with cold water during Turkish coffee brew preparation. As result of this brewing technique Turkish coffee brew has foamy textural properties and strong flavour (Caprioli et al., 2015; Hameed et al., 2018).

In previous studies on Turkish coffee, the effect of roasting on the volatile compounds of Turkish coffee brew was evaluated, but the ground coffee used in the preparation of Turkish coffee brew has not been evaluated yet (Kıvançlı and Elmacı, 2016; Ayseli et al., 2021). The aim of this study was to determine the volatile compounds of light, medium, and dark roasted ground coffees and Turkish coffees obtained from this light, medium, and dark roasted ground coffees.

Material and Method

Material

Light, medium, and dark roasted, fine ground Arabica coffee (*Coffea arabica* L.) samples were obtained from Selamlique Coffee (Haremlik Industry and trade Inc., Turkey).

Method

Turkish Coffee Brew Preparation

Turkish coffee brews were prepared using Turkish coffee machine (Arçelik, Turkey). Light, medium, and dark roasted ground coffee samples and bottled water (Nestle, Turkey) were used in Turkish coffee brewing. Coffee brews were prepared in accordance with instruction of Turkish coffee machine producer, and 5 g roasted, ground coffee and 65 mL water were used.

Volatile Compound Extraction

The extraction of ground coffee and Turkish coffee brew volatiles were performed using head space-solid phase microextraction (HS-SPME) technique. The extraction of coffee volatiles was implemented using Divinylbenzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PDMS) fiber (Supelco, USA). C7-C30 alkane mixture (Supelco, USA) was utilized in identification of volatiles. For the extraction of the volatile compounds 1.5 g ground coffee and 20 mL of Turkish coffee brew were used and the extraction was implanted by 50/30 µm DVB/CAR/PDMS fiber. The ground coffee was transferred to vials. The vials were closed hermetically with PTFE coated silicone septum, and the vials were put on a block heater at 60°C. The fiber was placed in HS of the sample, and the extraction of volatiles was continued for 30 min (Dadalı and Elmacı, 2021). At the end of the extraction time, fiber was taken from the vial and injected to gas chromatography – mass spectrometry (GC-MS). The adsorbed volatiles were desorbed in the injection port of GC-MS. Same steps were followed for Turkish coffee brew.

GC-MS Analysis

The analysis of ground coffee and Turkish coffee brew volatiles was performed using GC-MS (HP 6980 GC/HP-5973MS, Agilent Technologies). The separation of volatiles was carried out on DB-WAX capillary column (60 m × 0.25 mm, 0.50 µm film thickness, Agilent Technologies). The injector port was operated at 250°C and splitless injection mode was used. Helium was used as carrier gas and the flow rate was 1.6 mL/dk. The oven temperature programme was started at 50°C for 2 min, increased to 90°C at a rate of 5°C /min, reached to 220°C at a rate of 2°C/min and held at 220°C for 10 min (Akiyama et al., 2008). The identification of volatile compounds was implemented using Wiley and Nist libraries. Also, C7-C30 alkane mixture was injected at the same chromatographic conditions to calculate Kovats index of each volatile compound.

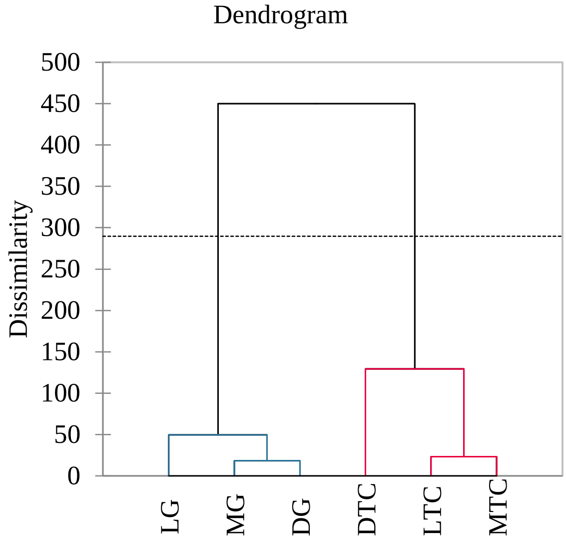

Figure 1. Classification of ground coffee and Turkish coffee brew samples (LG: Light roasted ground coffee, MG: Medium roasted ground coffee, DG: Dark roasted ground coffee, LTC: Turkish coffee brew prepared from light roasted coffee, MTC: Turkish coffee brew prepared from medium roasted coffee, DTC: Turkish coffee brew prepared from dark roasted coffee)

Statistical Analysis

The statistical analysis of volatile compound analysis was implemented using SPSS package program (Version 20, USA). The significant differences of volatile compound analysis results were evaluated using Analyzes of Variance (ANOVA) and Duncan multiple range test at 95% confidence level. Cluster analysis and principal component analysis (PCA) were performed to evaluate the relationship between light, medium, and dark roasted ground coffee and Turkish coffee brew. XLSTAT 2021 trial version was used for cluster analysis and PCA.

Results and Discussion

The volatile compound analysis results of light, medium, and dark roasted ground coffee and Turkish coffee brew prepared from light, medium and dark roasted ground coffee are shown in Table 1a, b. A total of 48 different volatile compounds from acid, alcohol, aldehyde, furan, furanone, ketone, lactone, phenol, pyrazine, pyridine, pyrrole, and thiophene chemical group were identified in the analysed ground coffee samples. In Turkish coffee brews prepared from light, medium, and dark roasted coffee, 34, 35, and 39 volatile compounds were determined, respectively. Pyrazines were the main volatile compound chemical class in light roasted, ground coffee and Turkish coffee brew prepared from light roasted coffee followed by volatile compounds from furan, pyrrole, and phenol groups. On the other hand, furans were the most abundant volatile compounds in medium, dark roasted ground coffee and Turkish coffee brew. The volatile compounds from pyrazine, phenol and pyrrole group followed furan group volatile compounds in ground coffee and Turkish coffee brew prepared from medium and dark roasted coffee.

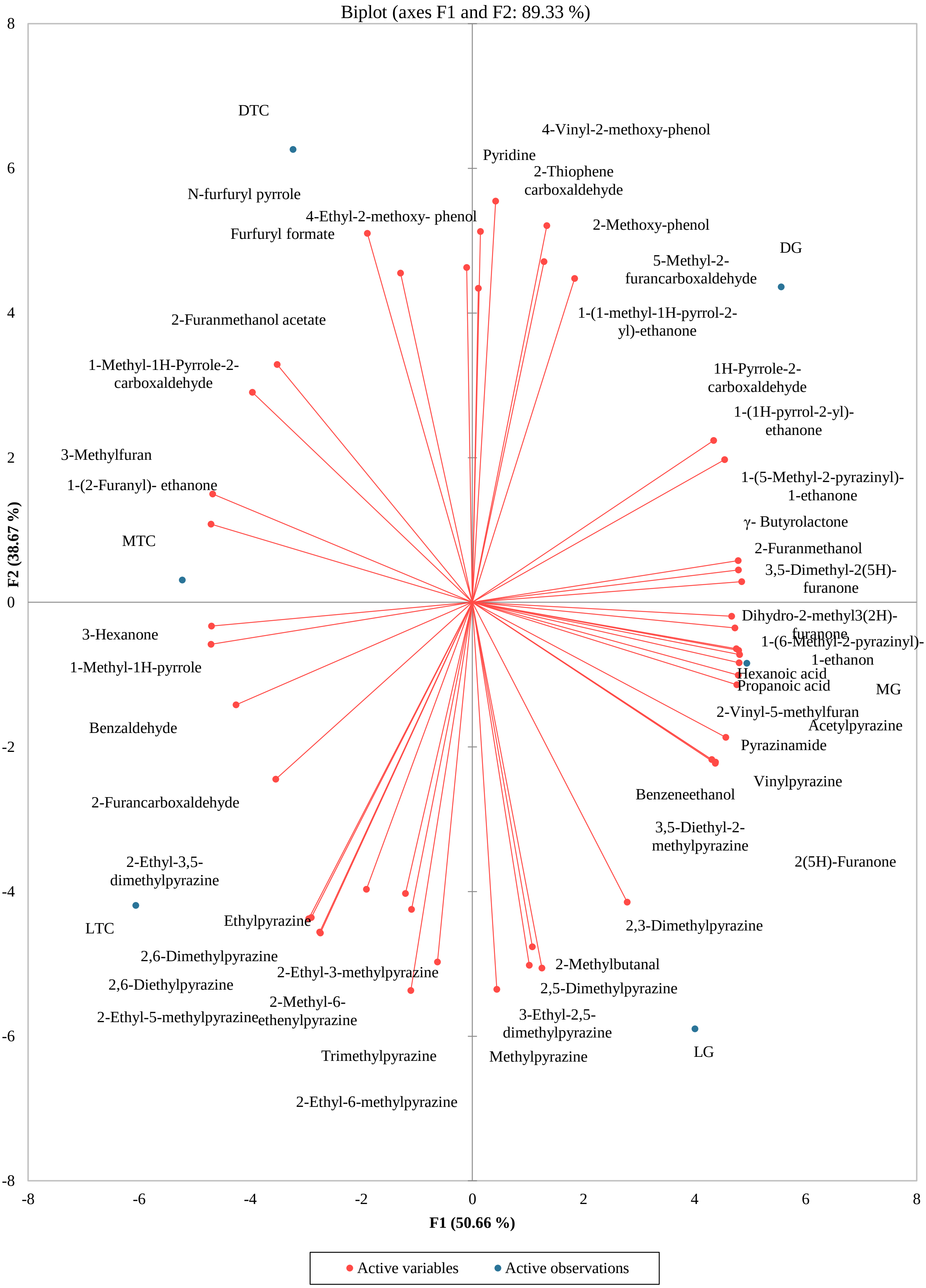

Figure 2. Biplot diagram of volatile compounds of ground coffee and Turkish coffee brew (LG: Light roasted ground coffee, MG: Medium roasted ground coffee, DG: Dark roasted ground coffee, LTC: Turkish coffee brew prepared from light roasted coffee, MTC: Turkish coffee brew prepared from medium roasted coffee, DTC: Turkish coffee brew prepared from dark roasted coffee)

Table 1a. Volatile compounds of ground coffee and Turkish coffee brew (mg/kg)[1,2]

K. indeks	Volatile compound	Ground coffee			Turkish coffee brew		
		Light	Medium	Dark	Light	Medium	Dark
	Acid						
1572	Propanoic acid	0.12±0.03^{a}	0.12±0.02^{a}	0.13±0.02^{a}	ND	ND	ND
1872	Hexanoic acid	0.72±0.05^{a}	0.89±0.04^{b}	0.85±0.05^{b}	ND	ND	ND
Total		0.84±0.04	1.01±0.05	0.98±0.06	-	-	-
	Alcohol						
1920	Benzeneethanol	0.48±0.05^{b}	0.28±0.06^{a}	0.27±0.03^{a}	ND	ND	ND
Total		0.48±0.05^{b}	0.28±0.06^{a}	0.27±0.03^{a}	-	-	-
	Aldehyde						
929	2-Methylbutanal	0.41±0.12^{c}	0.24±0.04^{b}	0.10±0.04^{a}	0.20±0.01^{ab}	0.23±0.03^{b}	0.11±0.02^{a}
1559	Benzaldehyde	0.25±0.02^{b}	0.14±0.00^{a}	0.15±0.06^{a}	1.77±0.03^{e}	0.82±0.08^{d}	0.70±0.06^{c}
Total		0.66±0.10^{c}	0.38±0.03^{a}	0.25±0.05^{a}	1.97±0.02^{f}	1.04±0.04^{e}	0.81±0.06^{d}
	Furan						
881	3-Methylfuran	0.12±0.00^{a}	0.14±0.01^{a}	0.17±0.02^{a}	1.07±0.11^{b}	1.16±0.12^{b}	1.24±0.20^{b}
1085	2-Vinyl-5-methylfuran	0.10±0.01^{a}	0.14±0.01^{c}	0.12±0.02^{b}	ND	ND	ND
1492	2-Furancarboxaldehyde	9.45±0.99^{b}	10.65±0.36^{c}	7.22±0.19^{a}	12.86±0.97^{d}	14.09±0.64^{e}	9.02±0.35^{b}
1519	Furfuryl formate	0.57±0.01^{a}	0.60±0.03^{a}	0.83±0.06^{b}	0.58±0.03^{a}	0.77±0.12^{ab}	1.59±0.22^{c}
1544	1-(2-Furanyl)- ethanone	1.49±0.05^{a}	1.56±0.05^{a}	1.49±0.07^{a}	2.58±0.06^{b}	2.96±0.13^{c}	2.65±0.12^{b}
1563	2-Furanmethanol acetate	3.88±0.05^{a}	3.57±0.03^{a}	6.87±0.26^{b}	12.20±0.38^{c}	13.38±0.25^{d}	23.94±0.49^{e}
1610	5-Methyl-2-furancarboxaldehyde	5.92±0.20^{a}	11.77±0.19^{b}	12.82±0.97^{c}	6.36±0.41^{a}	10.92±0.91^{b}	11.32±0.34^{b}
1695	2-Furanmethanol	17.83±0.98^{d}	19.40±1.17^{e}	21.66±0.62^{f}	6.50±0.73^{a}	8.17±0.30^{b}	9.53±0.25^{c}
Total		39.36±0.78^{a}	47.83±0.61^{c}	51.17±0.33^{d}	42.16±1.29^{b}	51.44±1.18^{d}	59.28±0.25^{e}
	Furanone						
1283	Dihydro-2-methyl3(2H)-furanone	0.30±0.04^{a}	0.47±0.03^{c}	0.42±0.10^{bc}	ND	ND	ND
1549	3,5-Dimethyl-2(5H)-furanone	0.19±0.02^{a}	0.33±0.03^{c}	0.29±0.02^{b}	ND	ND	ND
1762	2(5H)-Furanone	0.35±0.00^{c}	0.30±0.01^{b}	0.18±0.05^{a}	ND	ND	ND
Total		0.84±0.05^{b}	1.10±0.06^{c}	0.89±0.04^{b}	0.30±0.02^{a}	0.33±0.04^{a}	0.24±0.02^{a}
	Ketone						
1051	3-Hexanone	0.18±0.03^{a}	0.23±0.02^{ab}	0.19±0.08^{a}	0.44±0.04^{c}	0.40±0.10^{c}	0.32±0.05^{bc}
Total		0.18±0.03^{a}	0.23±0.02^{ab}	0.19±0.08^{a}	0.44±0.04^{c}	0.40±0.10^{c}	0.32±0.05^{bc}
	Lactone						
1673	γ- Butyrolactone	0.64±0.05^{b}	0.60±0.04^{b}	0.84±0.06^{c}	ND	ND	0.20±0.04^{a}
Total		0.64±0.05^{b}	0.60±0.04^{b}	0.84±0.06^{c}	-	-	0.20±0.04^{a}
	Phenol						
1898	2-Methoxy-phenol (Guaiacol)	0.41±0.05^{a}	0.66±0.06^{c}	1.12±0.08^{d}	0.43±0.02^{ab}	0.53±0.08^{b}	1.06±0.04^{d}
2071	4-Ethyl-2-methoxy- phenol	0.17±0.02^{a}	0.15±0.02^{a}	0.41±0.01^{c}	0.24±0.03^{b}	0.21±0.00^{b}	0.39±0.00^{c}
2239	4-Vinyl-2-methoxy-phenol	3.00±0.29^{a}	3.53±0.09^{b}	4.10±0.28^{c}	3.03±0.17^{a}	3.65±0.17^{b}	4.23±0.14^{c}
Total		3.57±0.27^{a}	4.34±0.12^{b}	5.63±0.16^{c}	3.69±0.16^{a}	4.39±0.16^{b}	5.67±0.14^{c}
	Pyrazine						
1301	Methylpyrazine	8.36±0.61^{d}	6.92±0.38^{c}	6.09±0.57^{b}	8.16±0.47^{d}	6.70±0.06^{bc}	4.16±0.08^{a}
1358	2,5-Dimethylpyrazine	4.98±0.31^{d}	3.01±0.05^{c}	1.99±0.04^{a}	3.17±0.12^{c}	2.50±0.14^{b}	1.75±0.11^{a}
1365	2,6-Dimethylpyrazine	3.37±0.18^{c}	2.58±0.19^{b}	1.88±0.20^{a}	3.68±0.55^{c}	3.23±0.42^{c}	2.43±0.25^{ab}
1374	Ethylpyrazine	3.08±0.25^{c}	2.80±0.28^{bc}	2.54±0.03^{b}	3.60±0.13^{d}	3.58±0.29^{d}	1.45±0.18^{a}
1389	2,3-Dimethylpyrazine	0.97±0.09^{d}	0.76±0.03^{c}	0.62±0.03^{ab}	0.67±0.09^{bc}	0.53±0.05^{a}	0.54±0.02^{a}
1423	2-Ethyl-6-methylpyrazine	4.16±0.11^{c}	3.18±0.10^{b}	2.37±0.10^{a}	4.36±0.52^{c}	3.58±0.35^{b}	1.96±0.22^{a}
1430	2-Ethyl-5-methylpyrazine	3.45±0.06^{c}	2.02±0.08^{b}	1.34±0.07^{a}	4.81±0.51^{d}	3.15±0.15^{c}	1.90±0.16^{b}
1443	2-Ethyl-3-methylpyrazine	1.89±0.10^{c}	1.61±0.09^{bc}	1.01±0.14^{a}	1.60±0.24^{bc}	1.65±0.18^{bc}	1.49±0.17^{b}
1450	Trimethylpyrazine	2.10±0.10^{c}	1.32±0.03^{b}	1.22±0.05^{b}	2.36±0.12^{d}	1.24±0.28^{b}	0.93±0.08^{a}
1472	2,6-Diethylpyrazine	0.54±0.04^{c}	0.41±0.02^{b}	0.27±0.03^{a}	0.66±0.02^{d}	0.49±0.05^{c}	0.37±0.07^{b}
1477	Vinylpyrazine	0.33±0.02^{b}	0.29±0.02^{b}	0.22±0.08^{a}	ND	ND	ND
1480	3-Ethyl-2,5-dimethylpyrazine	7.19±0.36^{d}	5.62±0.22^{c}	4.48±0.09^{b}	6.96±1.17^{d}	3.70±0.57^{ab}	3.31±0.48^{a}
1503	2-Ethyl-3,5-dimethylpyrazine	1.23±0.07^{b}	0.81±0.07^{a}	0.83±0.07^{a}	1.57±0.39^{c}	0.86±0.01^{a}	0.87±0.07^{a}
1521	2-Methyl-6-ethenylpyrazine	1.55±0.08^{c}	1.05±0.03^{b}	0.78±0.07^{a}	1.78±0.20^{d}	1.44±0.18^{c}	1.08±0.10^{b}
1527	3,5-Diethyl-2-methylpyrazine	0.32±0.01^{c}	0.23±0.01^{b}	0.18±0.02^{a}	ND	ND	ND
1669	Acetylpyrazine	0.90±0.09^{c}	0.83±0.09^{bc}	0.75±0.05^{b}	ND	ND	0.10±0.01^{a}
1705	1-(5-Methyl-2-pyrazinyl)-1-ethanone	0.57±0.03^{b}	0.81±0.02^{d}	0.75±0.03^{c}	ND	ND	0.27±0.04^{a}
1713	1-(6-Methyl-2-pyrazinyl)-1-ethanon	1.07±0.04^{b}	1.08±0.07^{b}	1.19±0.11^{c}	0.13±0.03^{a}	0.10±0.01^{a}	0.14±0.01^{a}
1755	Pyrazinamide	0.84±0.02^{b}	0.82±0.04^{b}	0.82±0.10^{b}	0.20±0.02^{a}	0.25±0.04^{a}	0.23±0.05^{a}
Total		46.91±1.03^{f}	36.18±0.48^{d}	29.34±0.29^{b}	43.69±0.99^{e}	32.99±0.93^{c}	22.99±0.54^{a}

[1]: Results are given as arithmetic mean±standard deviation. There is a statistical difference between the values shown with different symbols on the same row ($P<0.05$). [2]: ND: Not detected. K: Kovats

Table 1b. Volatile compounds of ground coffee and Turkish coffee brew (mg/kg)[1,2]

K. indeks	Volatile compound	Ground coffee			Turkish coffee brew		
		Light	Medium	Dark	Light	Medium	Dark
				Pyridine			
1223	Pyridine	1.36±0.14[a]	1.20±0.09[a]	2.21±0.36[c]	1.51±0.18[ab]	1.54±0.35[ab]	1.95±0.29[bc]
Total		1.36±0.14[a]	1.20±0.09[a]	2.21±0.36[c]	1.51±0.18[ab]	1.54±0.35[ab]	1.95±0.29[bc]
				Pyrrole			
1149	1-Methyl-1H-pyrrole	0.21±0.03[a]	0.17±0.01[a]	0.21±0.08[a]	3.41±0.16[c]	3.18±0.23[c]	1.61±0.16[b]
1659	1-Methyl-1H-Pyrrole-2-carboxaldehyde	0.90±0.05[a]	0.94±0.01[a]	1.02±0.11[a]	1.38±0.12[b]	1.61±0.03[c]	1.92±0.14[d]
1688	1-(1-methyl-1H-pyrrol-2-yl)-ethanone	0.74±0.04[a]	0.80±0.07[a]	1.08±0.26[b]	0.58±0.07[a]	0.57±0.11[a]	1.18±0.10[b]
1865	N-furfuryl pyrrole	0.37±0.08[a]	0.71±0.05[b]	0.94±0.10[bc]	0.69±0.13[b]	1.00±0.02[c]	1.21±0.29[d]
1983	1-(1H-pyrrol-2-yl)- ethanone	1.04±0.07[bc]	1.24±0.03[c]	1.74±0.51[d]	ND	0.30±0.00[a]	0.76±0.03[b]
2085	1H-Pyrrole-2-carboxaldehyde	0.47±0.03[a]	0.93±0.02[b]	1.07±0.06[c]	ND	ND	0.50±0.05[a]
Total		3.73±0.10[a]	4.79±0.06[b]	6.06±0.70[c]	6.06±0.35[c]	6.67±0.24[cd]	7.18±0.18[d]
				Thiophene			
1709	2-Thiophene carboxaldehyde	0.20±0.02[a]	0.36±0.01[b]	0.44±0.04[c]	0.19±0.04[a]	0.44±0.01[c]	0.47±0.02[c]
Total		0.20±0.02[a]	0.36±0.01[b]	0.44±0.04[c]	0.19±0.04[a]	0.44±0.01[c]	0.47±0.02[c]
				Unknown			
1324	Unknown	0.16±0.02[a]	0.26±0.04[b]	0.16±0.04[a]	ND	ND	ND
1413	Unknown	0.09±0.02[a]	0.15±0.00[c]	0.11±0.01[b]	0.30±0.02[e]	0.33±0.05[ef]	0.24±0.03[d]
1553	Unknown	0.37±0.01[a]	0.33±0.05[a]	0.36±0.02[a]	ND	0.66±0.02[b]	0.67±0.08[b]
1635	Unknown	0.12±0.01[a]	0.17±0.02[b]	0.19±0.02[b]	ND	ND	ND
1759	Unknown	0.19±0.01[b]	0.27±0.01[c]	0.41±0.03[d]	ND	ND	0.12±0.01[a]
1799	Unknown	0.11±0.04[a]	0.38±0.02[c]	0.34±0.02[b]	ND	ND	ND
1913	Unknown	0.20±0.03[c]	0.14±0.01[b]	0.14±0.03[b]	ND	0.10±0.01[a]	0.10±0.01[a]
Total		1.24±0.06[c]	1.71±0.05[d]	1.71±0.06[d]	0.30±0.02[a]	1.10±0.04[b]	1.13±0.07[c]

[1]: Results are given as arithmetic mean±standard deviation. There is a statistical difference between the values shown with different symbols on the same row (P<0.05). [2]: ND: Not detected. K: Kovats

Pyrazines are formed in remarkable amounts during roasting from the Maillard reaction between amino acids and sugars (Flament, 2001). Many pyrazines contribute to roasted aromas of coffee and associated with burnt and roasted flavours (Agresti et al., 2008). Pyrazines are known to be abundant in coffee, and over 80 of such compounds were previously identified (Makri et al., 2011; Madihah et al., 2013). Prolonged roasting conditions of coffee causes pyrazine loses due to the decomposition. As a result of decomposition, light roasted coffee and Turkish coffee brewed from light roasted coffee contains more volatile compounds from the pyrazine group than medium and dark roasted ground coffee and medium, dark roasted Turkish coffee brew (Table 1). A decrease in the area percentage of pyrazines was observed with the increase in the degree of roasting in both ground coffee and Turkish coffee brew. Methylpyrazine was determined to be the most abundant volatile compound from pyrazine class in all ground coffee and Turkish coffee brews. Methylpyrazine and 3-ethyl-2,5-dimethylpyrazine were main volatiles of pyrazine group and responsible from roasted, nutty, and earthy sensory characteristics of coffee (Bressanello et al., 2018; Caporaso et al., 2018). Vinylpyrazine and 3,5-diethyl-2-methylpyrazine volatile compounds having lower area percentage values were not detected in any Turkish coffee brew, although they were found in ground coffee. Acetylpyrazine and 1- (5-methyl-2-pyrazinyl) -1-ethanone were determined only in Turkish coffee brew prepared from dark roasted coffee among Turkish coffee brews.

Furans formed as result of heating or roasting of foods have various sources (Lee et al., 2017). These mechanisms are related mainly to thermal degradation of carbohydrates, pyrolysis of sugars at high temperature, oxidation of polyunsaturated fatty acids and decomposition of ascorbic acid and its derivatives (Crews and Castle, 2007). Guenther et al. (2010) revealed that dark roasted coffee contained higher furan levels. The content of volatiles from furans increased with roasting. In this study, the area percentages of furans in light, medium and dark roasted ground coffee were %39.36, 47.83, and 51.17, respectively. Similar increasing trend in area percentage of furans were observed in Turkish coffee brews (P<0.05). Furans were main volatile compounds of medium, dark roasted ground coffee and Turkish coffee brew obtained from medium, dark roasted ground coffee. A total of 8 furans were detected in light, medium, and dark roasted ground coffee. The area percentage of 2-furancarboxaldehyde, 2-furanmethanol acetate, 5-methyl-2-furancarboxaldehyde, and 2-furanmethanol were higher than other volatiles from furan group for all samples. These volatile compounds contribute to sweet-spicy, caramel, burnt, smokey, cherry, almond characteristics of coffee (Flament 2002; Caporaso et al., 2018; Sarghini et al., 2019). On the other hand, 2-vinyl-5-methylfuran was not determined in ground coffee and in any of the Turkish coffee brews.

Pyrroles were formed through the thermal process and pyrolysis of proline or trigonelline. The compounds have aromas that are burnt-like, sweet and smoky (Cappucio, 2005; Lee et al., 2017; Mottram, 2007). The area percentage of pyrroles increased by roasting both in ground coffee and Turkish coffee brews (P<0.05). 1H-Pyrrole-2-carboxaldehyde was not detected in light and medium roasted Turkish coffee brew, 1-(1H-pyrrol-2-yl)- ethenone was not determined only in Turkish coffee brew from light roasted coffee. Consistent with our study, Kıvançlı and Elmacı (2016) also determined an increase in pyrrole content of Turkish coffee brews with roasting.

Volatiles from phenol class 2-methoxy-phenol, 4-ethyl-2-methoxy- phenol and 4-vinyl-2-methoxy-phenol were present in coffee samples. A significant increase was detected in area percentage of phenols of all coffee samples with roasting (P<0.05). This increase was explained by generation and releases of phenol compounds with coffee roasting (Sunarharum et al., 2014).

Pyridines are generated from Amadori intermediates thermal processes or pyrolysis of amino acids. Also, trigonelline and chlorogenic acids act as a precursor of pyridines (Petisca et al., 2013). The area percentage of pyridines in dark roasted ground coffee was significantly higher than light, medium roasted ground coffee (P<0,05). In addition, pyridines of Turkish coffee brew prepared from dark roasted coffee was higher than Turkish coffee brew prepared from light and medium roasted coffee (P<0,05).

Aldehyde class of all coffee samples included 2-methylbutanal and benzaldehyde. Moreover, the area percentage of aldehydes of both ground coffees and Turkish coffee brews significantly reduced as result of increase in roasting (P<0.05). It was revealed that volatiles which are nonthermal origin such as aldehydes decrease with roasting (Gonzalez-Rios et al., 2007a; Poyraz et al., 2016).

γ-butyrolactone was the only member of lactone class of coffee volatiles. Although γ- butyrolactone were determined in all ground coffees, it was only detected in Turkish coffee prepared from dark roasted coffee. γ-butyrolactone area percentage of dark roasted coffee was higher than light and medium roasted coffee (P<0.05). According to previous study γ- butyrolactone was found in Turkish coffee brew and its content was higher in Turkish coffee brew from dark roasted coffee. It gives fatty-pleasant odour to coffee (Ayseli et al., 2021). γ-butyrolactone was the degradation product of chlorogenic acid and was produced more at higher roasting degrees (Moon and Shibamoto, 2009).

In our study, thiazole at a very low level was detected in roasted ground coffee and Turkish coffee brew. Volatiles from thiazole were detected by Kıvaçlı and Elmacı (2016) and Ayseli et al. (2021), but not by Amanpour and Selli (2016) in Turkish coffee brew. Likewise, Kıvaçlı and Elmacı (2016) observed an increased in 2-thiophenecarboxaldehyde area percentage with roasting.

3-Hexanone was the only volatile compound from ketone class which was detected in coffee samples. It exhibits sweet, fruity odour in coffee (Steen et al., 2017) and the area percentage of 3-hexanone increased with coffee roasting (P>0.05). In the previous Turkish coffee studies 3-hexanone was not detected in any Turkish coffee brew (Kıvaçlı and Elmacı, 2016; Amanpour and Selli, 2016; Ayseli et al., 2021),

Propanoic acid and hexanoic acid from acid class, benzene ethanol from alcohol class, dihydro-2-methyl-3(2H)-furanone, 3,5-dimethyl-2(5H)-furanone, 2(5H)-furanone from furanone class were found in roasted and ground coffee samples. On the other hand, none of them was detected in Turkish coffee brews.

According to the result of the cluster analysis applied to the volatile compounds of coffee samples, two main groups were formed. It was determined that roasted, ground coffee samples constituted one group, and Turkish coffee brews constituted the second group. Among roasted and ground coffee samples, medium and dark roasted ground coffees formed a subgroup. It was revealed that Turkish coffee brew obtained from light and medium roasted coffee constitutes a sub-group among Turkish coffee brews (Figure 1).

PCA was applied to determine volatile components that are effective in differentiation of coffee samples. According to PCA results hexanoic acid, benzeneethanol, 2-vinyl-5-methylfuran, 5-methyl-2-furancarboxaldehyde, 2-furanmethanol, dihydro-2-methyl3(2H)-furanone, 3,5-dimethyl-2(5H)-furanone were effective in differentiation of medium and dark roasted ground coffee. On the other hand, benzaldehyde, 2-furancarboxaldehyde, 2-furanmethanol acetate, 3-hexanone, 4-ethyl-2-methoxy- phenol, 2,6-dimethylpyrazine, ethylpyrazine, 2-ethyl-5-methylpyrazine, 2-ethyl-3-methylpyrazine, 2,6-diethylpyrazine, 2-methyl-6-ethenylpyrazine, and 1-methyl-1H-pyrrole were effective in grouping of Turkish coffee brew obtained from light and medium roasted coffee (Figure 2).

Conclusion

As a result of this study, volatile compounds from acid, alcohol, aldehyde, furan, furanone, ketone, lactone, phenol, pyrazine, pyridine, pyrrole, and thiophene class were detected in light, medium and dark roasted ground coffee. On the other hand, volatile compounds from aldehyde, furan, ketone, lactone, phenol, pyrazine, pyridine, pyrrole, and thiophene group were detected in Turkish coffee brews. Pyrazines were the main volatile compounds in light roasted ground coffee and Turkish coffee prepared from light roasted ground coffee, while the volatile compounds from furan group were higher in medium, dark roasted ground coffee and Turkish coffee brew of medium, dark roasted coffee. Although a decrease in the volatile compounds of alcohol, aldehyde, and pyrazine group was detected by roasting, an increase was observed in the volatile compounds of the furan, lactone, pyridine, and pyrrole group. In general, the effect of roasting on the volatile compounds' area percentage of roasted and ground coffee were similarly reflected in Turkish coffee brew of same roasting degree. With the Turkish coffee preparation method, not all the volatile compounds in ground coffee are extracted into the coffee brew. None of the volatile compounds from the acid, alcohol, furanone group were transferred from the ground coffee to coffee drink by the Turkish coffee preparation method.

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