Comparing Botanical Origin and Volatile Compounds of Some Turkish Honey Samples

Bazı Türkiye Balları'nın Botanik Kökeni ile Uçucu Bileşiklerinin Kıyaslanması

Research Article

Ömür Gençay Çelemli
Hacettepe University, Science Faculty, Department of Biology, Ankara, Turkey

ABSTRACT

The aim of this study is to determine relations exist between microscopic analysis and chemical profile in honey samples collected from Turkey. For this purpose, nine honey samples were collected. Eight of them were obtained from different locations of Turkey (Adana, Erzincan, Erzurum, Düzce, Rize, Hatay) and one from market shelf. The samples were grouped according to their botanical origins after microscopic analysis. According to the results of microscopic analysis, we found that four of them are multifloral, three of them are chesnut, one of them is *Calluna* and the last one is honeydew honey. The volatile compounds of the honey samples were determined by Solid Phase Microextraction/Gas Chromatography and Mass Spectrometry (SPME/GC-MS) method. The results showed that it is impossible to standardize the multifloral honeys in chemical composition base. According to our results "Aminoacetophenone" can be a marker compound for chesnut honeys, "Nonanal" for *Calluna* honey. Definite marker compound could'nt be identified for investigated honeydewhoney in this research.

Key Words
Honey, chesnut, *Calluna,* honeydew honey

ÖZET

Bu çalışmanın amacı Türkiye'den toplanan bal örneklerinin mikroskobik analizi ve kimyasal profili arasındaki ilişkiyi belirlemektir. Bu amaçla dokuz bal örneği toplanmıştır. Bal örneklerinin sekiz tanesi Türkiye'nin farklı bölgelerinden (Adana, Erzincan, Erzurum, Düzce, Rize, Hatay), bir tanesi ise marketten temin edilmiştir. Mikroskobik analizlerden sonra, örnekler botanik kökenlerine göre gruplandırılmıştır. Mikroskobik analiz sonuçlarına göre, dört bal örneğinin multifloral, üç örneğin kestane balı, bir örneğin püren ve bir tanesininde salgı balı olduğu tespit edilmiştir. Bal örneklerinin uçucu bileşikleri Katı Faz Mikroözütleme/ Gaz Kromatografisi ve Kütle Spektrometresi (SPME/GC-MS) ile belirlenmiştir. Sonuçlar multifloral balların kimyasal içerik bazında standardize olmasının imkansız olduğunu göstermiştir. Sonuçlara göre "Aminoasetofenon" bileşiğinin kestane balları için, "Nonanal" bileşiğinin ise Calluna balı için belirleyici bileşik olabileceği gösterilmiştir. Bu çalışmada incelenen salgı balı için kesin bir belirleyici bileşik tanımlanamamıştır.

Anahtar Kelimeler
bal, kestane, Calluna, salgı balı

Article History: Received: Jun 17, 2014; Revised: Sep 11, 2014; Accepted: Oct 17, 2014; Available Online: Dec 27, 2014.

Correspondence to: Ö. G. Çelemli, Hacettepe University, Science Faculty, Department of Biology, 06800, Ankara, Turkey
Tel: +90 (312) 297 71 61 Fax: +90 (312) 299 20 28 E-Mail: gencay@hacettepe.edu.tr

INTRODUCTION

Honey is a unique food product consisting of carbohydrates, amino acids, proteins, organic acids, vitamins, minerals and various phytochemicals. It is produced by bees from the nectar collected from a large variety of flowers and its chemical composition, physical, sensory and biological properties depend on the nectar source [1]. Floral honey is made by honey bees from the nectar of blossoms, while honeydew honey is prepared from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants. Differentiation between floral and honeydew honey is a response to consumer demands; in many countries nectar honey is valued more highly than honeydew honey but, in other countries, honeydew honey is preferred [2].

Honey has been reported to contain about 200 substances and is considered as an important part of traditional medicine. It has been used in ethnomedicine since the early humans, and in more recent times its role in the treatment of burns, gastrointestinal disorders, asthma, infected wounds and skin ulcers has been rediscovered [3]. Owing to the high number of volatile components, the aroma profile represents a "fingerprint" of the honey, which could be used to determine its origin. For example phenols and benzene derivative have been found characteristics for chesnut and lime tree unifloral honeys, acetoin has been mentioned as a eucalyptus honey marker by previous studies [4].

Honey has been traditionally used for different purposes and has a great potential to serve as a natural food antioxidant. In recent years much attention has been focused on the use of natural dietary antioxidants as an effective protection against oxidative damage [5].

Traditionally, the determination of the floral origin of honey has been achieved by the analysis of the pollen present in honey. The method is based on the identification of pollen by microscopic examination [6]. Many analytical methods (optical rotation, electrical conductivity etc.) are using to determine the botanical origin of honey. Microscopic analysis is able to detect the botanical origin much more exactly than other analytical methods [7]. Honey always includes numerous pollen grains (mainly from the plant species foraged by honey bees) and honeydew elements (likle wax tubes, algae and fungal spores) that altogether provide a good fingerprint of the environment where the honey comes from. Pollen analysis can therefore be useful to determine and control the geographical and botanical origin of honeys. Moreover, pollen analysis provides some important information about honey extraction, filtration, fermentation, some kinds of aldurteration and hygienic aspects such as contamination with mineral dust, soot, or strach grains [8].

Honey can never be derived from a single botanical source. The term "unifloral" honey is used to describe honey produced mostly from one plant species. Generally, the pollen content for a honey to be called "unifloral" should be at least 45% of the total pollen count [6].

Due to the location of Turkey, different climatic conditions and plant cover can be seen in this country. Turkey includes three phyto-geographical and seven geographical regions. There are 9222 naturally grown species in Turkey and 3000 of these are endemic [9]. Because of rich plant cover and different climatic conditions the content and variety of Turkish honey are very rich.

Turkey has an important place among the world for producing honey. Since in Turkey producing honey amount was 94245 tons in 2011 [10]. Owing to its flora, a wide range of honey types (*Astragalus, Helianthus, Pine, Rhododendron,* Chesnut, Clover, *Thyme, Lavandula* etc.) are producing in Turkey.

Although in Turkey honey is produced and consumed on a large scale, there is a lack of information on the comparative biochemical properties of Turkish honey. By this study we characterized some Turkish honey samples firstly according to their botanical origin and then chemical composition. We tried to find a relationship with their botanical origin and chemical composition.

MATERIALS AND METHODS

Honey samples

Eight of honey samples were provided directly from beekeepers in 2011 and one of them was taken from market. The samples were stored at a laboratory temperature (22±2°C) until the time of analysis.

Determination of botanical origin of honey samples by microscopic analysis

The floral sources of honey samples were determined by the melissopalynological method. The materials were prepared for examination under the microscope according to the method of Louveaux et al., [11]. Honey samples were divided according to their botanical origin into several groups (Blossom honey and honeydew honey) and subgroups (Bloossom honey divided into multifloral, castanea, Calluna).

Besides the determination of botanical origin, the total pollen number (TPN) of all samples were calculated according to Moar [12].

Headspace-Solid Phase Microextraction (HS-SPME) analysis

To determine volatile compounds of honey samples HS-SPME method was used. The main advantages of SPME method are simplicity, high sensivity, small sample volume, and lower cost per analysis [4] .

5 g honey and 5 mL bidistilled water were mixed in a 20 ml vial, allowed to equilibrate at 50°C for 15 min with magnetic stirring. The vial was conditioned at 50°C for 15 min in a water bath prior to SPME headspace sampling. Then the SPME needle was introduced through the septum, and the fibre was exposed in the vial headspace for 40 min. A temperature of 50°C was maintained during headspace sampling. The SPME device (Supelco Co, Bellefonte, PA, USA) used was equipped with a divinylbenzene fibre coated with polydimethylsiloxane. The fibre was then retracted into the needle, and the SPME holder was used for GC injection.

Gas Chromatography-Mass Spectrometry (GC-MS) analysis

Aroma compounds are present in honey at very low concentarions as complex mixtures of volatile components of different functionality and relatively low molecular weight. Since gas chromatography/mass spectrometry combines high seperation efficiency and sensitivity and provides qualitative and quantitative data for these compounds, it is usually the technique of choice for aroma profile determination [4].

A GC 6890N instrument from Agilent (Palo Alto, CA, USA) coupled with a mass detector (MS5973; Agilent) was used for the analysis of honey samples. Experimental conditions of the GC-MS system were as follows: a DB 5MS column (30 m x 0.25 mm, 0.25 μm film thickness) was used and the flow rate of the mobile phase (He) was set at 1 ml/min. In the GC part, temperature was kept for 8 min at 35°C and then increased to 60°C at 6°C/min intervals followed by 4°C/min to 160 °C and 20°C/min to 200°C/min and kept at 200°C for 1 min.

Organic compounds in propolis samples were identified in Wiley's NIST Mass Spectral Library, if the obtained comparison scores were higher than 95%. Otherwise, fragmentation peaks of the compounds were evaluated, and the compounds were identified using the memory background for the identification of the compounds that appeared in GC-MS chromatograms. Contents of individual compounds in the ethanol extract–are given in percent of the total compounds in the sample. This was the standard way to quantify most organic compounds in the honeysamples. Variations were not higher than 5%.

RESULTS

Microscopic analysis results

According to the microscopic analysis results, four honey samples (1-4) were determined as multifloral, three honey samples as chesnut (5-7), one as *Calluna* (8) and one as honeydew honey (9). The colecting areas of samples, identified pollen families and taxa are given in Table 1. TPN_{10} values are given in Table 2. The microphotographs of some idendified pollen are given in Figure1-5.

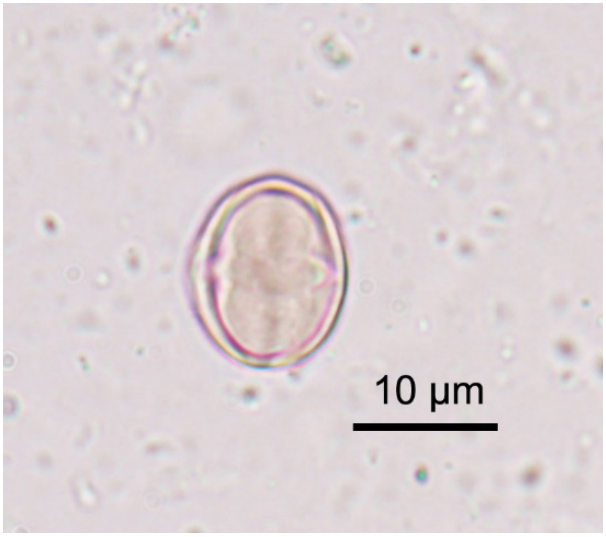

Figure1. *Castanea sativa* pollen (X100).

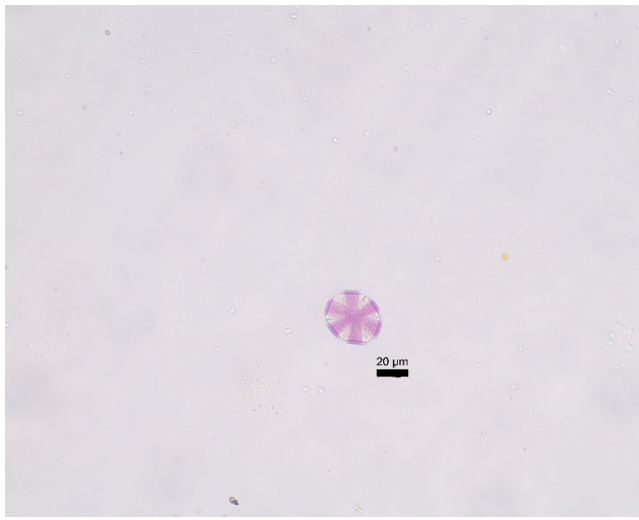

Figure 2. Lamiaceae pollen (X40).

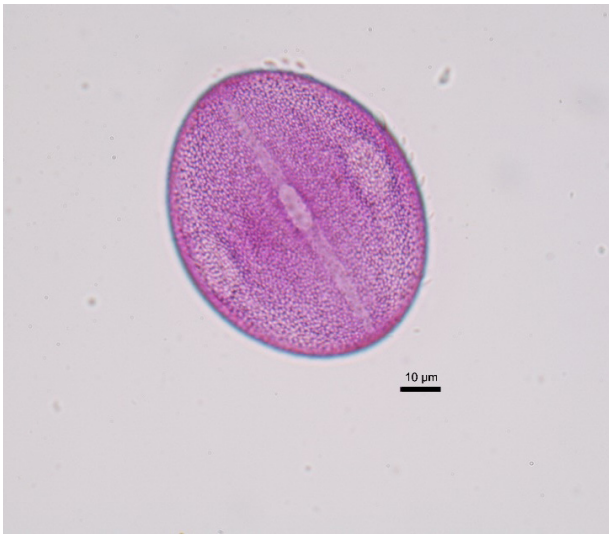

Figure 3. Cistaceae pollen (X100).

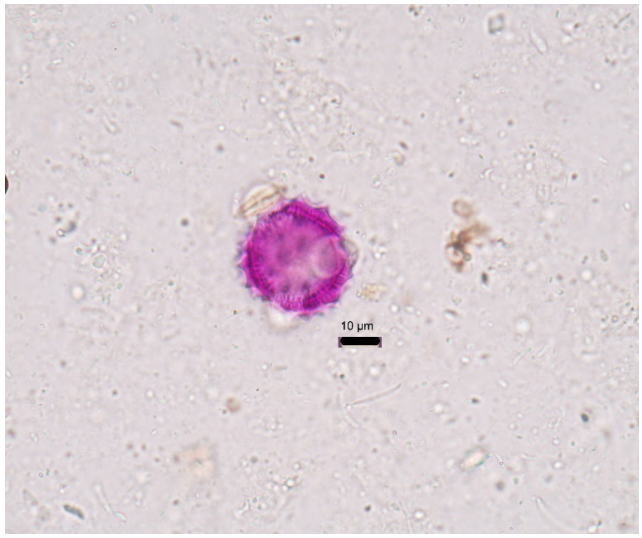

Figure 4. Asteraceae pollen (X100) and spores characteristic for honeydew honey.

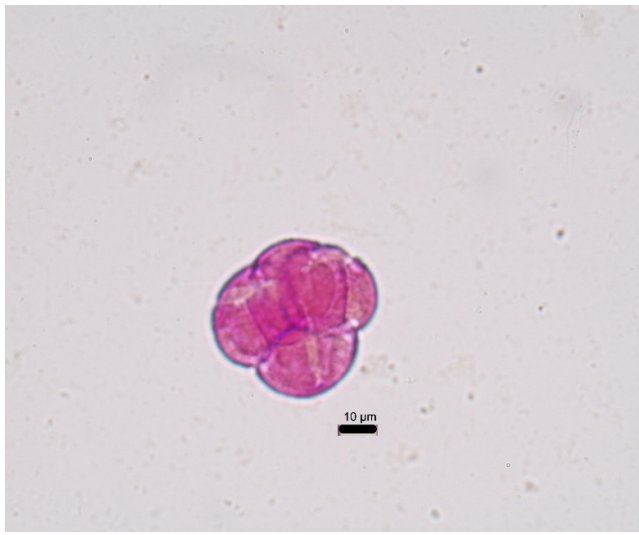

Figure 5. *Calluna* spp.pollen (X100).

Table 1. Identified plant families and taxa in pollen slides of honey samples.

		Multifloral				**Chesnut**			**Calluna**	**Honeydew honey**
Sample No		1	2	3	4	5	6	7	8	9
Collecting area		**Adana**	**Erzincan**	**Erzurum**	**Rize**	**Düzce**	**Düzce**	**Rize**	**Hatay**	**Market shelf**
Plant family	Plant taxa									
Apiaceae					1					58
Asteraceae			2		1					45
Berberidaceae		-	107							
Betulaceae									1	
Boraginaceae		4	5	1						
	Myosotis spp.				7					
Brassicaceae		3	3							3
Campanulaceae				2	5					
Caryophylaceae			1	2	30			1		1
Chenopodiaceae		2								19
Cistaceae		14	17	13	7	2				2
Dipsecaceae			1		2					
Ericaceae			1	1	1			1		
	Calluna spp.								104	
Fabaceae		23	38	11	34	5	5	5	16	32
Fabaceae	*Astragalus* spp.									
	Hedysarum spp.				65					
	Medicago spp.									
	Onobrychis spp.		8	1					6	24
	Trifolium spp.	1			30					
Fagaceae	Castaneae sativa	65	12	2	3	191	195	190	71	
Lamiaceae		15	1	2		2				9
	*Teucrium*spp.									
Lauraceae					3					
Papaveraceae					3					
Pinaceae										2
Poaceae		71			1					3
Polygonaceae	*Rumex* spp.	1								
Rosaceae		-	-		7		-	5	1	2
Salicaceae			4							
Scrophulariaceae		1								
	Verbascum spp.								1	

Table 2. TPN_{10} values of the honey samples

Honey Samples	TPN_{10} values
1	52 335
2	17 140
3	7672
4	105 081
5	128 294
6	119 365
7	366 226
8	210 444
9	53 911

TPN values show the pollen richness or poorness of the honey samples. It changes from 7672 to 366226 in investigated samples. The values bigger than 100000 indicades the richness of honey by pollen amount. So 4-8 samples are more valuble in terms of the pollen compare to the other samples.

Chemical analysis results

We determined volatile compounds of samples by solid phase micro-extraction gas chromatography-mass spectrometry (SPME/GC-MS).

Identified compound groups are included alcohols, aldehydes, aliphatic acids and their esters, carboxylic acids and their esters, hydrocarbons, ketones, cinnamic acids and their estes, terpens. Some mostly observed compounds are given in Table 3.

DISCUSSION

Honey sample 1 determined as multifloral, contains significantly "Linalool" with a high ratio (45.16%). This compound was observed only in sample1. Moreira et al., [13] observed the "linalool oxide" compound in cashew honey. If we look at the results in terms of pollen content; honey sample 1 contains pollen of *Castanea sativa*, and the taxa of Poaceae, Fabaceae, Lamiaceae, Cistaceae families in high amounts. But the members of Poaceae and Cistaceae families have no nectar production, they have only pollen production. Different from other investigated multifloral honeys, sample 1 contains pollen of *Rumex* spp. and the taxa of Chenopodiaceae Scrophulariaceae families in minor amounts, while the other multiflorla honeys don't contain thse pollen. The most distinctive feature of sample 1, from the other multifloral honey (2-4) , is containing pollen of *Castanea sativa* and, the taxa of Lamiaceae, Poaceae families in higher amounts. Also it was showed by previous studies, plants belong to the Lamiaceae family produce linalool compound [14]. As seen from Table 3 sample 1 also contain compound Caryophyllene in minor amounts (0.52%). This compound is producing by members of Lamiaceae family as well [14]. Owing to microscopic and chemical analysis, we can say that sample 1 can be sourced from mainly nectar of plants belong to the Lamiaceae family.

We couldn't observe so much volatile compounds for sample 2. All determined compounds found in minor amounts. The compounds specific for sample 2 are: "2-Propanol,1-propoxy (0.26%)", "3-Hexen-1-ol (1.25%). The other identified compound "1,5-Heptadien-3-yne (2.75%)" was also found in sample 3(1.25%), sample 5 (0.03%) and sample 9 (0.85%). Radovic et al. [15] found "3-hexen-1-ol" compound in chesnut honey. In its pollen count results we can see chesnut pollen. So this is not a suprising result. The pollen content of sam ple 2 shows differences significantly by containing pollen belong tothe taxa of Berberidaceae family in high amounts, while the other eight honey samples don't contain any pollen belong to the Berberidaceae family. Also different from other multifloral honeys it contains pollen belong to the taxa of Salicaceae family in minor amounts.

The most remarkable compound is "Benzeneacetaldehyde" with a ratio of 24.62%, but this compound was observed in Calluna honey (sample 8) too with a quite high ratio (22.55%). Besides this "Benzaldehyde,3-methyl-"(1.97%),"5-Hexenal,4-methylene"(0.49%), "2,4-Pentedienenoic acid" (0,06%), "1-Pentyne" (0.23%), "Octatriene (3.66%)", "2,5-Octadiene (1.9%), " 3-methylenecyclohexene (0.25%)" were observed only in this sample. This sample has minor pollen amount compare to the others. It contains mostly pollen of taxa belong to the Cistacea and Fabaceae families. As it is known the plants belong to the Cistaceae family have no nectar production, this honey can be sourced from mainly nectar of Fabaceae species.

Table 3. Some identified chemical compounds in honey samples by GC-MS.

Compounds	1	2	3	4	5	6	7	8	9
Aldehydes									
Benzaldehyde, 4-methoxy- (CAS)								2.94	
Benzaldehyde, 3-methyl-			1.97						
Benzaldehyde (CAS)	0.42				0.35				
2-Furancarboxaldehyde (CAS)								15.41	
Nonanal								24.07	
Benzeneacetaldehyde			24.62					22.55	
Lilac aldehyde A				8.10					
5-Hexenal, 4-methylene-			0.49						
Cinnamic acids and their esters									
.Beta.-Methylcinnamic acid	0.28								
Hydrocarbons									
Benzofuran, 2-methyl-					3.89				
1,2-Dimethyl cyclopropene	0.30				0.49				0.30
1-Pentyne			0.23						
3-Hexene, 1-(1-ethoxyethoxy)-									0.13
2-ethyl-1-hexen-3-yne					0.17				
3-Octyne (CAS)					0.67				
4-Octyne				0.50					
7-Chlorobicyclo[4.1.0]hept-3-ene								0.31	
1,3,5-Cycloheptatriene (CAS)								0.70	
HEPTA-1,2,6-TRIENE									
1,3,6-Octatriene, 3,7-dimethyl-, (Z)- (CAS)				0.24	0.76				
1,2,7-Octatriene			3.66						
1,3,5,7-Cyclooctatetraene					0.08				
1,3-Cycloheptadiene	0.54								
2,3-Hexadiene, 2-methyl-				1.31					
1,6-Dimethoxyhexa-2,4-diyne								0.40	
1,5-Heptadien-3-yne		2.75	1.25		0.03				0.85
1,5-Heptadiyne				0.72	0.10				
2,5-Octadiene			1.90						
Ethenylidenecyclohexane					0.52				
3-Methylenecyclohexene			0.25						
Ketones									
2-Phenyl-2-tipyl-acenapthenone								2.42	
Ethanone, 1-(2-furanyl)- (CAS)								1.44	
4-Aminoacetophenone						14.62			
2-Methylenecyclopropyl Phenyl Ketone						0.32			
3-Aminoacetophenone					36.04				
Terpen									
Trans-Caryophyllene	0.52								
ALPHA-PINENE, (-)-									0.69
LINALOOL	45.16								
Trans-Linalool oxide							10.48		

The most remarkable compound for sample 4 is Lilac aldehyde observed only in this sample with a ratio of 8.10%. The lilac compounds occur in plant species of many families, such as Caryophyllaceae (Dianthus spp., *Silene* spp. and), Rosaceae (*Prunus padus*), Lamiaceae (*Origanum vulgare*), Onagraceae (*Gaura longiflora*), Orchidaceae (*Platanthera* spp.), Polemoniaceae (*Phlox paniculata*), Salicaceae (*Salix* spp), Violaceae (*Viola etrusca*), Actinidiaceae (*Actinidia*), Rubiaceae (*Cephalanthus occidentalis*), Vitaceae (*Vitis vinifera* cv. Moscato bianco), Asteraceae (*Artemisia pallens*, *Eupatorium cannabinum*), Oleaceae (*Syringa vulgaris*), and are found in several honeys [16]. This sample contains pollen of *Hedysarum* spp, *Trifolium* spp., and taxa of Caryophyllaceae family in significant amounts. This sample can be sourced from mostly members of Caryophyllaceae family. Unlike other multiflorals (sample 1-3) it contains pollen of *Myosotis* spp., and the taxa of Apiaceae, Lauraceae, Papavearacea, Rosaceae families.

As understood from the results for multifloral honey samples it is imposibble to say marker significant compounds. Since their botanical sources show differences.

From chesnut honeys (5,6,7) sample 5 contains much more volatile compounds. It contains" 3-Aminoacetohenone" in a amount of (36.4%). This compound was found only in sample5. Also it contains "Benzaldehyde, 2-Butanol,3-methyl-, 5-Hexenoic acid, 3-Pyridinecarboxylic acid, 2H-Tetrazole-5-carboxylic acid, 2-phenyl-, 2H-1-Benzopyran, Benzofuran,2-methyl, 2-Ethyl-1-hexen-3-yne, 3-Octyne, 1,3,5,7-Cyclotatetraene, 1,7-Octadiyne,Ethenylidenecyclohexane, 8-oxabicyclo(4.3.0.)nona-1,3,5-dien-7-one, Benzeneprpanamine" in minor amounts different from other honey types. Similiar to our results 3-Aminoacetophenone the major compound of sample 5 was found as marker compounds for chesnut honey by previous studies [15].

Sample 6 determined as a chesnut honey contains "4-Aminoacetophenone"- in a ratio of 14.6% and "2-methylenecyclopropyl phenyl ketone" in a ratio of 0.32% different from other samples. Aminoacetophenone was found as marker compounds for chesnut honey by previous studies [3,15].

Sample 7 has Trans-Linalool oxide with a quite high amount (10.48%). *Trans*-Linalool oxide, was found in *Cashew* honey by previous studies [13] . Also "1,4-hexadiene,3,3,5-trimethyl-" was observed in sample 7. While for two chesnut honey (sample 5,6) we observed marker compound of chesnut honey, we could'nt find it in sample 7. It can be caused by the analyse process.

Sample 8 was evaluated as *Calluna* honey contains in highest amount compound is "Nonanal" (24.07%). This compound was observed in only sample 8. Besides this it contains "Benzeneacetaldehyde" with a high ratio (22.55%). But this compound was also found in sample 3 too. Besides these "1,3-cyclohexadiene-1-carboxyaldehyde, 2,6,6-trimethyl- (1.01%), Phenol, 2-methyl-5-(1-methylethyl)- (1.19%), Benzoic acid (0.54%), 1,2-Benzenedicarboxylic acid, di-2-propenyl ester (0.40%), 7-Chlorobicyclo (4.1.0) hept-3-ene (0.31%), 1,3,5-Cycloheptatriene (0.70%), 1,6-Dimethoxyhexa-2,4-diyne (0.40%), 2-Phenyl-2-tipyl-acenapthenone(2.42%), Ethanone, 1-(2-furanyl)- (1.44%) compounds were observed in sample 8.

In *Calluna* honey we observed aldehydes in big amounts compare to other samples. Especially 2-furancarboxyaldehyde (15.41%), Nonanal (24.07) were observed only in *Calluna* honey and with big amounts. From this compound nonanal was found in Eucalyptus honey by previous studies [4]. Abscisic acid, formerly reported as a characteristic compound of Calluna honey was also detected in Brassica, Tilia and Robinia honeys in similiar concentrations. Besides these, Phenylacetic acid, dehydrovomifoliol, (4-(3-oxo-1-butynyl)-3,5,5-trimethylcycloexene derrivatives, 1-Penten-3-ol, 4-methylbicyclo(2,2,2) octan-1-ol, enylacetaldehyde, isophorone were found in *Calluna vulgaris* honey by previous researches [15,17,18,19].

As understood from the results, there is no any acute distinscts for marker compounds of unifloral honeys. The researches give general informations. Since the factors that effect honey

compositon is so much. It can be cahnge according to climatic conditions, bee races etc.

Hexanoicacid,2,3-bis(acetyloxy)propyl ester (0.10%), Benzoic acid, 2-mercapto (5.17%),3-Hexene,1-(1-ethoxyethoxy) (0.13%), alpha.-pinene- (0.69%), butane,1-(1-methylethoxy)-(0.36%), Butane,2-ethoxy-(1.77%), 4H-Pyran-4-one,tetrahydro-(0.20%), 1-Buten-3-yne,2-tert-butyl- (0.18%) compounds were found in only sample 9. Honeydew honeys studied contain terpene compounds including linalool oxide, hotrienol, -terpineol, eugenol, car-2-en-4-one, two isomers of epoxylinalool, p-cymen-8-ol, and 2-hydroxycineol, most of which are also found in unifloral citrus, lavender, and eucalyptus honeys (Vazquez et al., 2006). According to Vazquez et al., (2006) "ethanone,1-(2-furanyl)- is characteristic of honeydew honeys, we found this compound in Calluna honey with a ratio of 1.44%. There is some disagreement over which compounds serve as markers for a given type of honey, perhaps because of differences between plant varieties, geographical origins, or beekeeping practises. Moreover, methods of extracting the volatile fraction may display a varying degree of selectivity and effectiveness depending upon the compounds involved [20].

By this research we tried to find marker compounds of some Turkish honey samples. As other researchers mentioned so much factors effect the content of honey samples. Even though the honey samples are sourced from the same origin, they can show varieties in their contents. Therefore we could give some general informations about marker compounds of some Turkish honey samples. This study can be a step for classification of Turkish honey according to their botanical origins. Since classified and marked products are always demanded mostly. Consumers prefer to buy product which one is more informative. Also this rersearch showed the importance of microscopic analysis to determine the botanical origin of honey sample.

REFERENCES

1. V. Kaškoniene, P.R. Venskutonis,V. Œksteryté, Carbohydrate composition and electrical conductivity of different origin honeys from Lithuania, Food Science and Technology, 43 (2010) 801.
2. M.L.Sanz, M. Gonzalez, C. Lorenzo, J. Sanz, I.M. Castro, I.M, A contribution to the differentiation between nectar honey and honeydew honey, Food Chemistry, 91 (2005) 313.
3. M. Küçük, S. Kolaylı, Ş. Karaoğlu, E. Ulusoy, C. Baltacı,F. Candan, F, Biological activities and chemical composition of three honeys of different types from Anatolia, Food Chemistry, 100 (2007) 526.
4. L.F.C., Glory, J.A. Pino, L.S. Santiago, E.S. Duch, A review of olatile analytical methods for determining the botanical origin of honey, Food Chemistry, 103 (2007) 1032.
5. S. Saxena, S. Gautam, A. Sharma, Physical, biochemical and antioxidant properties of some Indian honeys, Food Chemistry, 118 (2010) 391.
6. E. Anklam, A review of the analytical methods to determine the geographical and botanical origin of honey, Food Chemistry, 63 (1198) 549.
7. A. Pridal, L. Vorlova, Honey and its physical parameters, Czech J. Anim. Sci. 47 (2002) 439.
8. W.V.D. Ohe, L.P. Oddo, M.L. Piana, , M. Morlot, P. Martin, Harmonized methods of melissopalynology, Apidologie 35 (2004) 18.
9. H. Davis, Flora of Turkey and the East Aegean Islands, I-X, Edinburg University pres, Edinburg (1965-1988).
10. 10.TÜİK .2012. Website http://www.tuik.gov.tr.
11. J.Louveaux, A. Maurizio, G. Vorwohl, Internationale Komission fur lenenbotanik der I.U.B. Methodik der Melissopalynologie, Apidologie, 1 (1970) 193.
12. N.T. Moar, Pollen analysis of New Zealand Honey, Journal of Agricultural Research ,28 (1985) 38.
13. R.F.A. Moreira, L.C. Trugo, M. Pietroluongo, C.A.B. De Maria, Flavor composition of cashew (Anacardium occidentale) and Marmeleiro (Croton Species) honeys, Journal of Agricultural and Food Chemistry, 50 (2002) 7616.
14. P.M. Dewick, Medicinal Natural Products. 3rd ed. UK:Wiley Ltd. (2008)
15. B.S. Radovic, M. Careri, A. Mangia, M. Musci, M. Gerboles, E. Anklam, Contribution of dynamic headspace GC-MS analysis of aroma compounds to authenticity testing of honey, Food Chemistry, 72 (2001) 511.

16. S. Dötterl, D. Burkhardt, B. Weibbecker, A. Jürgens, S. Schütz, A. Mosandl, Linalool and lilac aldehyde/ alcohol in flower scents Electrophysiological detection of lilac aldehyde stereoisomers by a moth, Journal of Chromatography A, 113 (2006) 231.
17. C. Guyot, V. Scheirman, S. Collin, Floral origin markers of heather honeys: Calluna vulgaris and Erica arborea, Food Chemistry, 64 (1999) 3.
18. A.C. Soria, I. Martinez-Castro, J. Sanz, Analysis of volatile composition of honey by solid phase microextraction and gas chromatography and mass spectrometry, Journal of Seperation Science, 26 (2003) 793.
19. S.T. Tan, A.L. Wilkins, P.T. Holland, T.K. McGhie, Extractives from New Zealand honeys degraded caretenoids and other substances, Journal of Agricultural and Food Chemistry, 37 (1989) 1217.
20. L.C.Vazquez, M.C. Maroto, M.S.P. Coello, Volatile composition and contribution to the Aroma of Spanish Honeydew Honeys, Identification of a New Chemical Marker, Journal of Agricultural and Food Chemistry 54 (2006) 4809.