KSÜ Tarım ve Doğa Derg 27 (5), 1095-1104, 2024
KSU J. Agric Nat 27 (5), 1095-1104, 2024
https://doi.org/10.18016/ksutarimdoga.vi.1427402

Determination of Naphthalene Concentration in Honey a New Method using HS-GC/MS (Headspace-Gas Chromatography/Mass Spectrometry)

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ABSTRACT

Honey is considered by people as an important food, included in diets and used in the treatment of many diseases. Contamination of honey with harmful compounds can render it unsafe, as honey is known to naturally contain pesticides. These pests are transmitted to honey by environmental conditions or incorrect beekeeping practices. Naphthalene is used by beekeepers to prevent the honeycombs from holding moths. Naphthalene, which has carcinogenic properties, also causes different diseases. Therefore, the concentration of naphthalene in honey should not exceed a certain limit. For the determination of this, many different analysis methods are developed and applied. In this study, the naphthalene concentration of honey from Bingöl province and its districts, one of the important beekeeping centers in Türkiye, was determined by a new HS-GC/MS method that does not require sample preparation. No naphthalene concentration was detected in eight different honey samples. A concentration of 0.5 µg kg^{-1} was used as the detection limit. The fact that naphthalene concentration was not detected in kinds of honey from Bingöl province indicates that beekeepers do not use naphthalene and that naphthalene is not contaminated by environmental factors.

Biochemistry

Research Article

Article History
Received : 29.01.2024
Accepted : 06.03.2024

Keywords
Honey
Naphthalene
HS-GC/MS
Gas chromatography
Headspace

Baldaki Naftalin Konsantrasyonunun Yeni Bir Yöntemle HS-GC/MS (Headspace-Gaz Kromatografisi/Kütle Spektrometresi) ile Belirlenmesi

ÖZET

Bal, insanlar tarafından önemli bir gıda olarak görülmekte, diyetlerde yer almakta ve birçok hastalığın tedavisinde kullanılmaktadır. Şifa kaynağı olan bala zararlı bileşenlerin bulaşması balı zararlı hale getirebilir; zira balda pestisitlerin bulunduğu bilinmektedir. Bu zararlılar çevresel koşullar veya yanlış arıcılık uygulamaları ile bala bulaşmaktadır. Naftalin, arıcılar tarafından peteklerin güve tutmasını önlemek için kullanılmaktadır. Kanserojen özelliğe sahip olan naftalin, farklı hastalıklara da neden olmaktadır. Bu nedenle baldaki naftalin konsantrasyonunun belirli bir sınırı aşmaması gerekmektedir. Bunun tespiti için birçok farklı analiz yöntemi geliştirilmekte ve uygulanmaktadır. Bu çalışmada, Türkiye'nin önemli arıcılık merkezlerinden biri olan Bingöl ili ve ilçelerinden elde edilen balların naftalin konsantrasyonu, numune hazırlama gerektirmeyen yeni bir HS-GC/MS yöntemi ile belirlenmiştir. Sekiz farklı bal örneğinde naftalin konsantrasyonu tespit edilmemiştir. Tespit limiti olarak 0.5 µg kg^{-1}'lık bir konsantrasyon kullanılmıştır. Bingöl ilinden gelen ballarda naftalin konsantrasyonunun tespit edilmemiş olması, arıcıların naftalin kullanmadığını ve naftalinin çevresel faktörlerle kontamine olmadığını göstermektedir.

Biyokimya

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 29.01.2024
Kabul Tarihi : 06.03.2024

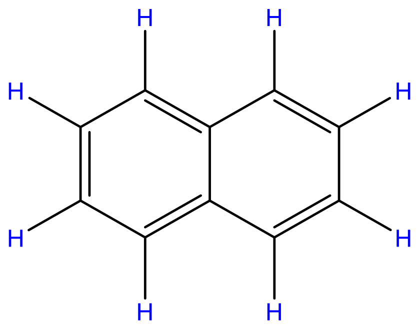
Anahtar Kelimeler
Bal
Naftalin
HS-GC/MS
Gaz Kromatografisi
Headspace

Atıf Şekli: İzol, E., (2024) Baldaki naftalin konsantrasyonunun yeni bir yöntemle HS-GC/MS (headspace-gaz kromatografisi/kütle spektrometresi) ile belirlenmesi. *KSÜ Tarım ve Doğa Derg 27* (5), 1095-1104. https://doi.org/10.18016/ksutarimdoga.vi.1427402

To Cite : İzol, E., (2024). Determination of Naphthalene Concentration in Honey a New Method using by HS-GC/MS (Headspace-Gas Chromatography/Mass Spectrometry. *KSU J. Agric Nat 27*(5), 1095-1104. https://doi.org/10.18016/ksutarimdoga.vi.1427402

INTRODUCTION

Honey, created because of bees collecting plant pollen and reacting it with their enzymes, has been a very important food source throughout human history (İzol, 2023a; İzol et al., 2021). Honey consumed as a source of healing contains rich bioactive components and shows extensive biological activities (İzol et al., 2023; Yapıcı et al., 2023). Honey is used for therapeutic purposes in functional and modern medicine (İzol, 2023b). However, honey, which is a source of healing, becomes harmful when it contains chemical residues such as pesticides (Turhan & İzol, 2023; Karakaş, 2022). Honey can be contaminated with polycyclic aromatic hydrocarbons from a variety of sources, such as forest fires, stubble burning, and industrial plants near apiaries, because of poor practices by beekeepers (İzol, 2023c). The widespread use of insecticides, fungicides, and acaricides in agricultural practices to control pests and bee diseases in beehives increases the possibility of direct or indirect contamination of honey.



$C_{10}H_8$

Figure 1. Chemical structure of naphthalene
Şekil 1. Naftalinin kimyasal yapısı

Naphthalene is used by beekeepers as a wax moth control agent, leaving residues on bees and bee products such as beeswax and honey (Bogdanov et al., 2004). Naphthalene is an important chemical that renders honey harmful (Topdemir et al., 2024). Naphthalene is a polycyclic aromatic hydrocarbon with the chemical structure $C_{10}H_8$. Naphthalene, whose chemical structure is shown in Figure 1, is a carcinogenic substance and has been found to cause many different types of cancer. It has also been found to cause nervous system disorders and liver damage in cases of ingestion, skin contact, and inhalation (Yost et al. 2021).

For this reason, the concentration of naphthalene in honey should be at a limit that does not harm human health or is not present at all. For this purpose, the naphthalene concentration of honey should be determined continuously, and the results should not exceed the upper limits specified by international organizations.

In this study, naphthalene concentrations of honey obtained from Bingöl province and districts, one of the important beekeeping centers of Türkiye, were determined by HS-GC/MS using a new method.

MATERIAL and METHOD

Chemicals

The naphthalene (molecular weight:128) standard, naphthalene-D8 (molecular weight:136) internal standard, and methanol used in the analysis process were obtained from Sigma Aldrich.

Localities where honey samples were collected

Honey samples were provided by beekeepers from all districts, including Bingöl Center. The villages and altitudes from which the honey was obtained are given in Table 1.

HS-GC/MS device data and analytical parameters

Experimental conditions and analytical parameters for the analysis are given in Tables 2 to 4.

Determination of naphthalene concentration in honey by HS-GC/MS

The determination of naphthalene concentration in honey was carried out based on a quantitative determination by HS-GC/MS. In this method, the naphthalene mass is determined based on the mass of the naphthalene-D8 internal standard. The samples are vaporized by heating in the headspace unit, and the vaporized molecules are sent to the GC column with the headspace needle, and the mass of naphthalene is determined by the MS detector.

Table 1. Locations and altitudes where honey samples were obtained
Çizelge 1. Bal örneklerinin elde edildiği yerler ve rakımlar

District Collected	Work Area (Village)	Altitude (m)
Bingöl Center	Emtağ	1661
Adaklı	Hasbağlar	1788
Genç	Sağgöze	1725
Karlıova	Halifan	1793
Kığı	Çiçektepe	1599
Solhan	Şerafettin	2549
Yayladere	Gökçedal	1623
Yedisu	Elmalı	1789

Table 2. GC Parameters
Çizelge 2. GC Parametreleri

Parameters	Specifications
Gas Chromatograph	PerkinElmer Clarus 690
Oven	35 °C for min, then 6 °C/min to 245 °C
Column	30 m, 0.25 mm, 0.25 µm Elite-WAX
Carrier Gas	Helium at 2.0 mL/min
Injector	A
Software	TurbaMass Ver. 6.1.2
Library	NIST

Table 3. MS Parameters
Çizelge 3. MS Parametreleri

Parameters	Specifications
Mass Spectrometer	PerkinElmer Clarus SQ 8T
Scan Range	35 to 250 Daltons
Scan Time	0.1 s
Interscan Delay	0.06 s
Inlet Line Temp	200 °C
Source Temp	180 °C
Multiplier	1700 V
Ionization	El+

Table 4. HS Trap Parameters
Çizelge 4. HS Trap Parametreleri

Parameters	Specifications
Headspace System	PerkinElmer TurboMatrix 40 HS Trap
Needle	120 °C
Transfer Line	140 °C, long, 0.25 mm i.d. fused silica
Vial Equilibration	90 °C for 10 min
Carrier Gas	Helium
GC Cycles	15 min
Column	20 psi
Inject	20 psi
Dry Purge	10 min
Oven	90 °C

First of all, the HS-GC/MS device was prepared according to the conditions specified in Tables 2 and 4. Then the calibration graph was plotted according to the established method. In the calibration graph, six different concentrations of naphthalene were used: 0.5, 1, 5, 10, 25, and 50 (µg kg^{-1}). Naphthalene solutions of six different concentrations were added to 20 mL headspace vials containing 1 g of honey, respectively. Naphthalene-D8 standard prepared at a concentration of 10 mg/kg was added to the vials in a volume of 30 µL, and the sealed vials were placed in a headspace autosampler. The analysis was started by typing the sequence information from the device software, and the calibration graph was generated. The calibration graph is given in Figure 2. In the calibration graph, the r^2 value was found to be 0.9959 and the calibration curve: was 0.950780 * x + 0.289365. The limit of detection (LOD) was calculated as 0.5 µg kg^{-1}.

For naphthalene analysis of honey samples, 1 g of each sample was weighed into a different vial, and 30 µL of naphthalene-D8 standard at a concentration of 10 mg kg^{-1} was added to all vials. The vials were sealed, placed in headspace autosamplers, and analyzed by writing down the sequence information. The results were calculated according to the calibration graph. Methanol was used as a solvent in all solutions prepared.

RESULTS and DISCUSSION

Naphthalene concentration in honey Results by HS-GC/MS

The results of the naphthalene concentrations of honey obtained from Bingöl province and its districts by HS-GC/MS are given in Table 5.

The naphthalene concentration in all honey samples was below the limit of quantification (LOQ) and could not be detected. Naphthalene and naphthalene-D8 chromatograms of honey samples are shown in Figures 3 to 10.

The appearance of a naphthalene peak in the chromatograms indicates the presence of naphthalene well below the detection limit of 0.5 µg kg^{-1}.

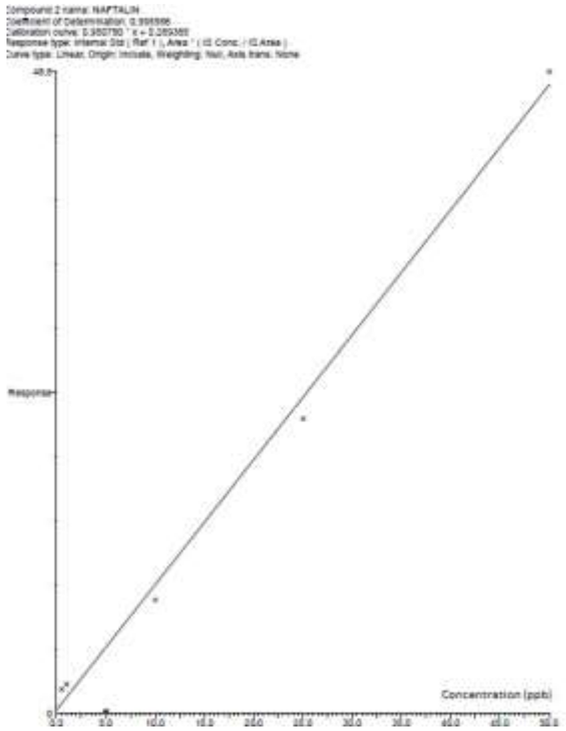


Figure 2. Calibration graph for naphthalene analysis in honey
Şekil 2. Balda naftalin analizi için kalibrasyon grafiği 1

Naphthalene is a polycyclic aromatic hydrocarbon. Natural sources of naphthalene include burning biomass and fossil fuels like coal tar and petroleum (Yost et al., 2021). The production of chemical intermediates (such as phthalic anhydrides), dyes, surfactants, leather tanning agents, dispersants, pesticides, resins, and solvents are the main industrial applications of naphthalene. Many consumer products that contain naphthalene are moth repellents and blocks of toilet deodorant (Turhan & İzol, 2023; Yost et al., 2021).

Animal studies and human case studies have provided most of the evidence linking naphthalene exposure to cancer and non-cancer health problems. Over the past ten years, hundreds of researches pertinent to the health impacts and mechanisms of naphthalene exposure have been published, contributing to the growing body of scientific literature defining naphthalene toxicity (U.S. EPA, 2021). Studies on rats have shown that exposure to naphthalene causes different types of cancer and some respiratory disorders. Studies have shown that naphthalene also causes hemolytic anemia (NTP, 2016).

Tablo 5. Naphthalene concentration results of honey samples
Çizelge 5. Bal örneklerinin naftalin konsantrasyon sonuçları

Honey Samples	Retention Time (RT)	Concentration (μg kg^{-1})
Bingöl Center	7.77;6	N.D.
Adaklı	7.77;2	N.D.
Genç	7.78;6	N.D.
Karlıova	7.78;9	N.D.
Kığı	7.78;16	N.D.
Solhan	7.78;12	N.D.
Yayladere	7.77;11	N.D.
Yedisu	7.78;11	N.D.

N.D.: Not Detected. Retention time is given in minutes. seconds; salisse

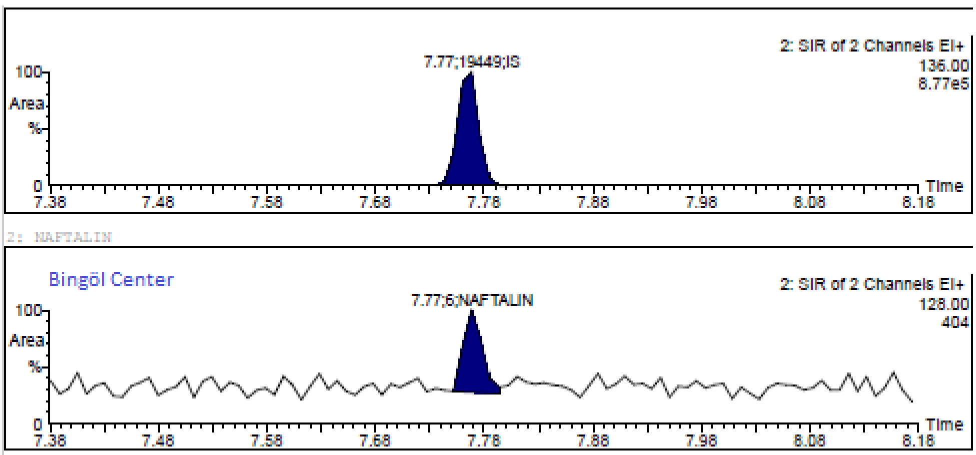


Figure 3. Naphthalene HS-GC/MS chromatogram of Bingöl center honey
Şekil 3. Bingöl merkez balının naftalin HS-GC/MS kromatogramı

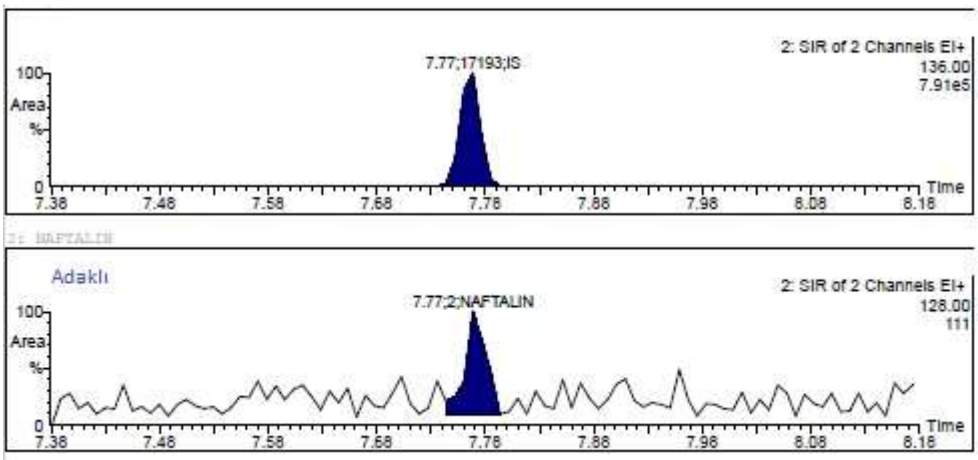


Figure 4. Naphthalene HS-GC/MS chromatogram of Adaklı honey
Şekil 4. Adaklı balının naftalin HS-GC/MS kromatogramı

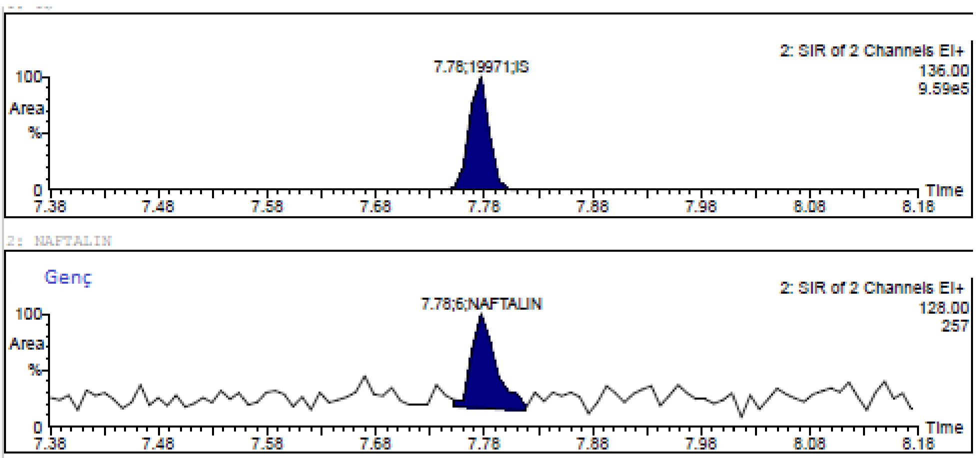


Figure 5. Naphthalene HS-GC/MS chromatogram of Genç honey
Şekil 5. Genç balının naftalin HS-GC/MS kromatogramı

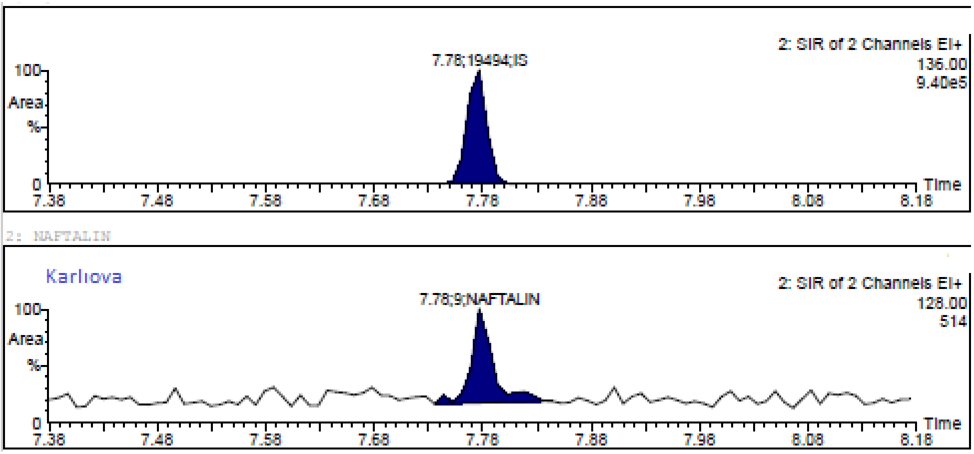


Figure 6. Naphthalene HS-GC/MS chromatogram of Karlıova honey
Şekil 6. Karlıova balının naftalin HS-GC/MS kromatogramı.

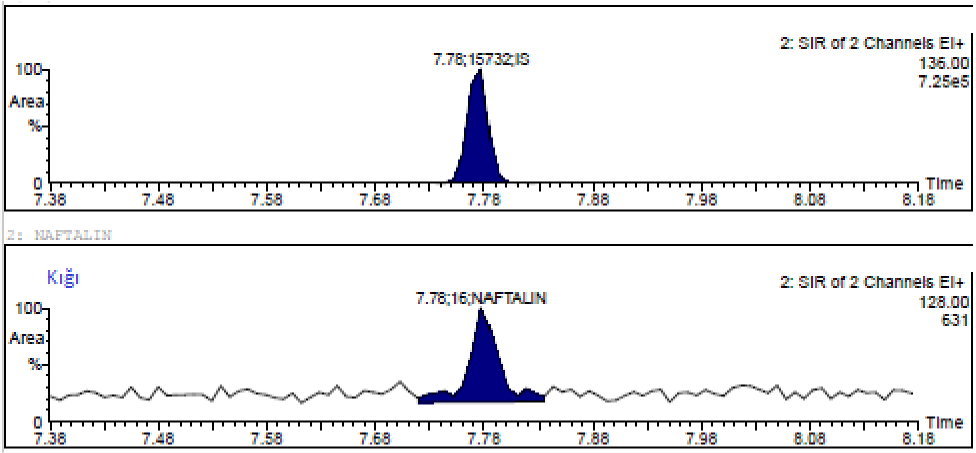


Figure 7. Naphthalene HS-GC/MS chromatogram of Kığı honey
Şekil 7. Kığı balının naftalin HS-GC/MS kromatogramı

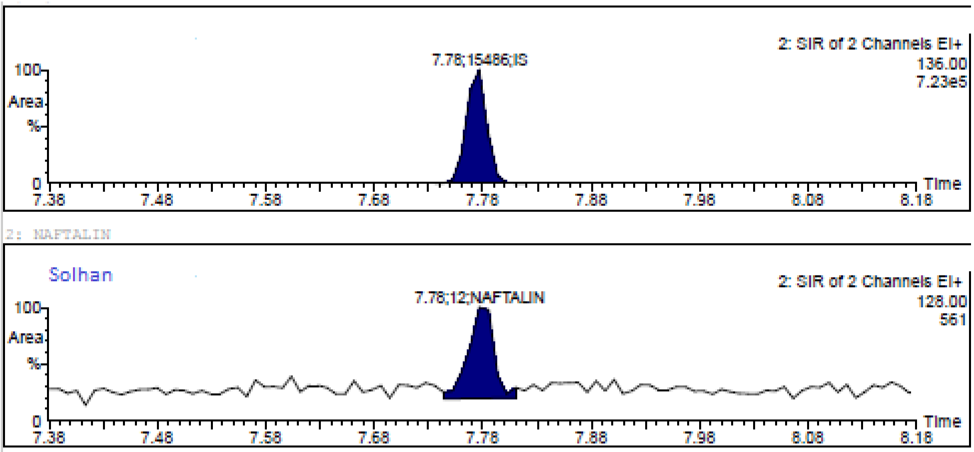


Figure 8. Naphthalene HS-GC/MS chromatogram of Solhan honey
Şekil 8. Solhan balının naftalin HS-GC/MS kromatogramı

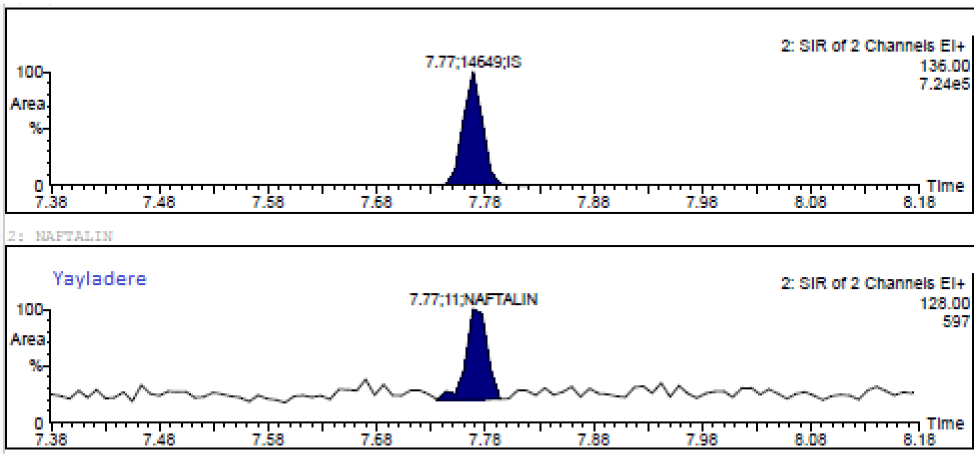


Figure 9. Naphthalene HS-GC/MS chromatogram of Yayladere honey
Şekil 9. Yayladere balının naftalin HS-GC/MS kromatogramı

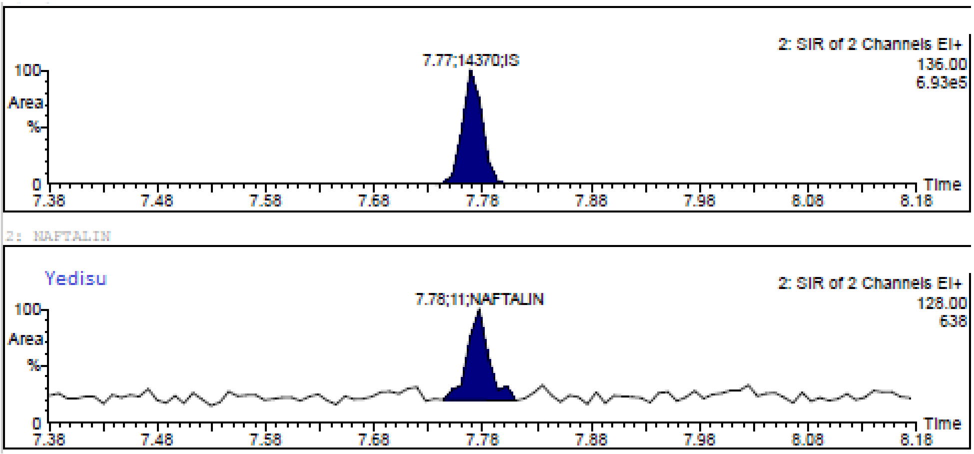


Figure 10. Naphthalene HS-GC/MS chromatogram of Yedisu honey
Şekil 10. Yedisu balının naftalin HS-GC/MS kromatogramı

Beekeeping methods and environmental factors are two examples of the many ways that bee products can get polluted. The primary risk of direct contamination of honey products, however, is beekeeping methods, particularly the use of chemicals like naphthalene inside the hives to protect honeybee combs from wax moths. These substances are dangerous volatile organic compounds, and prolonged exposure to them can have negative effects on the neurological system, kidney, heart, lung, and blood cells (Seidi et al., 2020; Aggrawal, 2006). Naphthalene has been used in many countries to reduce the effects of the *Galleria mellonella* pest on honeycombs (Koltsakidou et al., 2015). However, because of scientific studies, naphthalene was found to be harmful, and therefore many countries banned the use of naphthalene in honeycombs. However, some beekeepers have continued this habit. For this reason, many countries specify in their food codex honey communiqués the highest limit of naphthalene concentration in honey and report that honey exceeding these limits is not suitable for consumption. A value intended to give an exposure limit at which some protection to human health can be assumed is referred to as a "reference value." The most popular result of the dose-response assessment part of the National Research Council's risk assessment paradigm is reference values (NRC, 2009). A maximum residue limit of 10 µg/kg of naphthalene has been set by the European Union (EU) and Switzerland for food samples such as honey. In the Turkish Food Codex Honey Communiqué, the highest concentration of naphthalene for honey is accepted as 10 µg kg^{-1} (Anonymous, 2023). Numerous tests carried out in many nations, including Greece, Germany, and Switzerland, at various times, revealed that a significant number of honey samples were contaminated with naphthalene (Aggrawal, 2006).

Due to the harmful aspects of naphthalene, it is necessary to monitor naphthalene concentrations in significant and widely consumed foods, such as honey. So far, many papers have reported on the measurement of trace amounts of polycyclic aromatic hydrocarbons in different environmental, biological, and food samples (Poster et al., 2006; Santos et al., 2019; Bansal et al., 2017). These analytical techniques include gas chromatography with mass spectrometry (GC-MS) (Dobrinas et al., 2008), headspace gas chromatography with mass spectrometry (HS-GC/MS), gas chromatography with tandem mass spectrometry (GC-MS/MS) (Saitta et al., 2017), gas chromatography with ultrasound-assisted extraction (USAE)-GC/MS (Iwegbue et al., 2016), gas chromatography with matrix solid-phase dispersion (MSPD)-GC/MS (Albero et al., 2003), gas chromatography with flame ionization detection (GC-FID) or ion trap mass spectrometry (GC-IT-MS) (Russo et al., 2017), solidification of floating organic droplet-based dispersive liquid-liquid microextraction (SFOD-DLLME)-GC/MS (Fazaieli et al., 2020), and solid phase microextraction (SPME)-GC/MS (Tananaki et al., 2005; Tsimeli et al., 2008; Moniruzzaman et al., 2014; Bulut et al., 2014; Soria et al., 2003; Wang et al., 2020; Al-Alam et al., 2017). GC-MS techniques provide superiority over other techniques in terms of short analysis time, accurate and reliable results, advanced technology, and the application of different analysis methods. For this reason, it is the primary method, especially in the analysis of volatile components (Moliner-Martinez et al., 2015; Wang et al., 2014; Queiroz et al., 2019).

In this study, a method that can determine the concentration of naphthalene in honey without any extraction process has a short analysis time and high accuracy using an internal standard was developed.

Research on the naphthalene content of honey in Türkiye started in the 2000s. In a study, naphthalene concentration was investigated in 100 honey samples, and the naphthalene concentration was found to be 1.13 µg kg^{-1} in only 1 honey sample. It was not detected in other kinds of honey (Beyoğlu & Omurag, 2007). In the study in which 120 commercially strained honey samples produced in different climatic and geographical regions of Türkiye and offered for consumption in Ankara were analyzed for naphthalene residues, naphthalene was detected in 11 honey samples. It was determined that the concentration range of naphthalene in honey samples was 1.1–6.2 µg kg^{-1} (Şireli & Ülker, 2013). In another study, the effect of 60 days of aeration on the residue of naphthalene-treated foundation combs was investigated, and as a result, it was determined that there was a significant decrease in naphthalene concentration at the end of the specified period (Karacaoğlu et al., 2012). In the study in which the naphthalene concentration of 45 honey samples sold in the Bursa province of Türkiye was determined, naphthalene was not detected in honey samples using the method with a detection limit of 2 µg kg^{-1} (Tosunoğlu, 2016). In the study in which naphthalene was analyzed by the HS-SPME-GC/MS method, naphthalene was detected in only one of the 30 different honey samples obtained from the Mediterranean region. The concentration of naphthalene in the detected honey (8.76 µg kg^{-1}) was below the maximum value of 10 µg kg^{-1}. In addition, the naphthalene concentration in two honey samples was found to be below the detection limit in trace amounts (Muku et al., 2019).

In the study in which the naphthalene concentration of 90 strained honey samples obtained from different provinces in the Mediterranean region was investigated by GC/MS, naphthalene was detected in only 1 honey sample. The determined naphthalene concentration was 115.234 µg kg^{-1}. Method validation was also performed in this study (Gölge et al., 2017). In the study in which naphthalene concentrations of 30 strained and 30 honeycomb honey were determined by GC/MS, 3 honey samples were found to be 3, 3.9, and 8.9 µg/kg below the naphthalene limit value of 10 µg kg^{-1} in the Turkish Food Codex Honey Communiqué. Naphthalene was not detected in other honey samples (Çakar & Güler, 2019). In a study conducted in the UK, the concentration of naphthalene in 49 different honey samples was investigated. As a result of the study, naphthalene was not detected in honey samples (Castle et al., 2004). A new method for the detection of naphthalene in honey was developed and optimized by SPME-GC/MS. In the study, it was stated that salt addition, extraction temperature, and analysis time are important for the success of the method. In addition, naphthalene was not detected in the studied kinds of honey (Tsimeli et al., 2008). Similarly, in another study, a new method was developed to indicate the concentration of naphthalene in honey (Badertscher et al., 2010). In a study conducted in Nigeria, the concentration of 16 different polycyclic aromatic hydrocarbons collected from different parts of the country was determined by GC-MS. In the study, 40 honey samples were used, and naphthalene was not detected in the honey (22). In a study conducted in Greece, 90 unifloral honey samples were investigated for pesticide residues. Naphthalene was found at traceable levels in about 79% of the honey samples. However, 5.6% of them were above the limit value. This indicates that the combs were contaminated. In this study, it was also stated that naphthalene in honey may be of plant origin, as naphthalene was found in plants in the region studied (Harizanis et al., 2008).

CONCLUSION

Honey is a significant food in the human diet. Honey must therefore be free from foreign or harmful substances. Naphthalene is used to protect honeycombs, but it is very harmful to human health. Honey should therefore be analyzed regularly and should not be consumed if it contains more harmful components than the set limits. This is why new methods are being developed to analyze mothballs in honey. In this study, the naphthalene concentration of honey from Bingöl province and its districts, one of the important beekeeping centers in Türkiye, was determined using a new HS-GC/MS method. Eight different honey samples were investigated, and no naphthalene was detected. With this study, a new method was introduced to the world of science. The most significant feature that distinguishes this method from other methods is that it does not require any sample preparation or extraction. As a result of this study, because of scientific studies and pieces of training given to beekeepers, it has been observed that mothballs used for the protection of honeycombs are rarely used anymore.

Acknowledgments

I would like to thank Bingöl University Bee and Natural Products R&D and P&D Research and Application Center for supporting this study.

REFERENCES

Aggrawal, A. (2006). Agrochemical poisoning. *Forensic pathology reviews*, 261-327

Al-Alam, J., Fajloun, Z., Chbani, A., & Millet, M. (2017). A multiresidue method for the analysis of 90 pesticides, 16 PAHs, and 22 PCBs in honey using QuEChERS–SPME. *Analytical and Bioanalytical Chemistry*, *409*, 5157-5169.

Albero, B., Sánchez-Brunete, C., & Tadeo, J. L. (2003). Determination of polycyclic aromatic hydrocarbons in honey by matrix solid-phase dispersion and gas chromatography/mass spectrometry. *Journal of AOAC International*, *86*(3), 576-582.

Anonymous, (2023). Türk Gıda Kodeksi Bal Tebliği, Tarım ve Orman Bakanlığı, Ankara, 2023/37. https://www.resmigazete.gov.tr/eskiler/2023/11/20231124-5.htm

Badertscher, R., Kilchenmann, V., Liniger, A., & Gallmann, P. (2010). Determination of 1, 4-dichlorobenzene, naphthalene and thymol residues in honey using static headspace coupled with GC-MS. *J. ApiProduct & ApiMedical Sci*, *2*(3), 78-92.

Bansal, V., Kumar, P., Kwon, E. E., & Kim, K. H. (2017). Review of the quantification techniques for polycyclic aromatic hydrocarbons (PAHs) in food products. *Critical Reviews in Food Science and Nutrition*, *57*(15), 3297-3312.

Beyoğlu, D., Omurtag, G.Z. (2007). Occurrence of naphthalene in honey consumed in Turkey as determined by high pressure liquid chromatography. *Journal of Food Protection*,7, 7-15.

Bogdanov, S., Ruoff, K., & Oddo, L. P. (2004). Physico-chemical methods for the characterisation of unifloral honeys: a review. *Apidologie*, 35(Suppl. 1), S4-S17.

Bulut, G., Col, M., Derebasi, E., Erturk, O., Guney, F., & Yasar, N. (2014). Physicochemical and Residue Analysis of Honey from Black Sea Regıon of Turkey.

Castle, L., Philo, M., Sharman, M. (2004). The analysis of honey samples for residues of nitrobenzene and petroleum from the possible use of Frow mixture in hives. *Food Chemistry, 84*, 643-649.

Çakar, E., & Gürel, F. (2019). Süzme ve petekli balların pestisit, naftalin ve antibiyotik kalıntıları bakımından karşılaştırılması. *Mediterranean Agricultural Sciences*, *32*(3), 453-459.

Dobrinas, S., Birghila, S., & Coatu, V. (2008). Assessment of polycyclic aromatic hydrocarbons in honey and propolis produced from various flowering trees and plants in Romania. *Journal of Food Composition and Analysis*, *21*(1), 71-77.

Fazaieli, F., Afshar Mogaddam, M. R., Farajzadeh, M. A., Feriduni, B., & Mohebbi, A. (2020). Development of organic solvents-free mode of solidification of floating organic droplet–based dispersive liquid–liquid microextraction for the extraction of polycyclic aromatic hydrocarbons from honey samples before their determination by gas chromatography–mass spectrometry. *Journal of Separation Science*, *43*(12), 2393-2400.

Gölge, Ö., Hepsağ, F., Kılınççeker, O. (2017). Determination of naphthalene levels of honey in eastern mediterranean region. *Adyütayam 5*(2), 14-23.

Harizanis, P. C., Alissandrakis, E., Tarantilis, P. A., & Polissiou, M. (2008). Solid-phase microextraction/ gas-chromatographic/mass spectrometric analysis of p-dichlorobenzene and naphthalene in honey. *Food Additives and Contaminants*, *25*(10), 1272-1277.

Iwegbue, C. M., Tesi, G. O., Obi, G., Obi-Iyeke, G. E., Igbuku, U. A., & Martincigh, B. S. (2016). Concentrations, health risks and sources of polycyclic aromatic hydrocarbons in Nigerian honey. *Toxicology and Environmental Health Sciences*, *8*, 28-42.

İzol, E. (2023a). "Phytochemicals in Honey and Health Effects", In Honeybees, Plants and Health, ed. Koçyiğit M., İzol E., Haspolat Y.K., *Orient Publications,* 85-96. ISBN: 978-625-6598-03-4.

İzol, E. (2023b). "The Place of Bee Products in Functional Medicine", In Functional Medicine Part 2, ed. Haspolat Y.K., Atlı A., Aşır F., *Orient Publications,* 11-16. ISBN: 978-625-6893-11-5.

İzol, E. (2023c). Bazı Arı Ürünlerinin (Bal, Polen, Propolis, Arı Sütü ve Arı Ekmeği) LC-MS/MS ile Sekonder Metabolitlerinin ve Biyolojik Aktivitelerinin Belirlenmesi. Doktora Tezi. *Atatürk Üniversitesi Fen Bilimleri Enstitüsü*, Erzurum.

İzol, E., Kaya, E., &Karahan, D. (2021). "Investigation of Some Metals in Honey Samples Produced in Different Regions of Bingöl Province by ICP-MS. *Mellifera 21*(1), 1–17.

İzol, E., Gülçin, İ., Yılmaz, M.A. (2023). "Health Effects of Honey and Honey Sherbet with Spiritual and Scientific Sources", In Functional Foods, ed. Haspolat Y.K., Kavak V., Asena M., *Orient Publications,* 89-95. ISBN: 978-625-6893-99-3.

Karacaoğlu, M., Uçak Koç, A., Çerçi, A. (2012). Assessment of naphthalene residues in beeswax foundations stored in windscreen cabinets. *Asian Journal of Animal Science*, *6*(1),42-46.

Karakaş, G. (2022). Pestisit Kullanımının Bal Verimi Üzerine Etkisi; Panel Veri Analizi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 25*(5), 1163-1167.

Koltsakidou, A., Zacharis, C. K., Fytianos, K. (2015). A validated liquid chromatographic method for the determination of polycyclic aromatic hydrocarbons in honey after homogeneous liquid–liquid extraction using hydrophilic acetonitrile and sodium chloride as mass separating agent. *Journal of Chromatography A*, 1377, 46-54.

Moliner-Martinez, Y., Herráez-Hernández, R., Verdú-Andrés, J., Molins-Legua, C., & Campíns-Falcó, P. (2015). Recent advances of in-tube solid-phase microextraction. *TrAC Trends in Analytical Chemistry*, *71*, 205-213.

Moniruzzaman, M., Rodríguez, I., Rodríguez-Cabo, T., Cela, R., Sulaiman, S. A., & Gan, S. H. (2014). Assessment of dispersive liquid–liquid microextraction conditions for gas chromatography time-of-flight mass spectrometry identification of organic compounds in honey. *Journal of Chromatography A*, *1368*, 26-36.

Muku, C., Güçlü, G., & Selli, S. (2019). Doğu Akdeniz Bölgesi Ballarının Pestisit ve Naftalin Kalıntılarının LC/MS/MS ve HS-SPME GC/MS Teknikleriyle Belirlenmesi. *Çukurova Tarım ve Gıda Bilimleri Dergisi, 34*(2), 142-148.

NRC (National Research Council). (2009). Science and Decisions: Advancing Risk Assessment. Washington, DC: National Academies Press. http://dx.doi.org/ 10.17226/12209.

NTP. (2016). Naphthalene. Report on Carcinogens. 14 th ed. Research Triangle Park, NC: National Toxicology Program, https://ntp.niehs.nih.gov/ntp/roc/content/profiles/naphthalene.pdf [accessed 26 June 2021].

Queiroz, M. E. C., de Souza, I. D., & Marchioni, C. (2019). Current advances and applications of in-tube solid-phase microextraction. *TrAC Trends in Analytical Chemistry*, *111*, 261-278.

Poster, D. L., Schantz, M. M., Sander, L. C., & Wise, S. A. (2006). Analysis of polycyclic aromatic hydrocarbons (PAHs) in environmental samples: a critical review of gas chromatographic (GC) methods. *Analytical and bioanalytical chemistry*, *386*, 859-881.

Russo, M. V., Avino, P., & Notardonato, I. (2017). PAH residues in honey by ultrasound-vortex-assisted liquid-liquid micro-extraction followed by GC-FID/IT-MS. *Food Analytical Methods*, *10*, 2132-2142.

Saitta, M., Di Bella, G., Fede, M. R., Lo Turco, V., Potortì, A. G., Rando, R., ... & Dugo, G. (2017). Gas chromatography-tandem mass spectrometry multi-residual analysis of contaminants in Italian honey samples. *Food Additives & Contaminants: Part A*, *34*(5), 800-808.

Santos, P. M., del Nogal Sánchez, M., Pavón, J. L. P., & Cordero, B. M. (2019). Determination of polycyclic aromatic hydrocarbons in human biological samples: A critical review. *TrAC Trends in Analytical Chemistry*, *113*, 194-209.

Seidi, S., Abolhasani, H., Razeghi, Y., Shanehsaz, M., & Manouchehri, M. (2020). Electrochemically deposition of ionic liquid modified graphene oxide for circulated headspace in-tube solid phase microextraction of naphthalene from honey samples followed by online liquid chromatography analysis. *Journal of Chromatography A*, *1628*, 461486.

Soria, A. C., Martínez-Castro, I., & Sanz, J. (2003). Analysis of volatile composition of honey by solid phase microextraction and gas chromatography-mass spectrometry. *Journal of Separation Science*, *26*(9-10), 793-801.

Şireli, U.T. Ülker, H. (2013). Süzme ballarda GCMS metodu ile naftalin kalıntısının incelenmesi. *Ankara Üniversitesi Bilimsel Araştırma Projeleri,* BAP No: 12H3338002 p:22.

Tananaki, C., Zotou, A., & Thrasyvoulou, A. (2005). Determination of 1, 2-dibromoethane, 1, 4-dichlorobenzene and naphthalene residues in honey by gas chromatography–mass spectrometry using purge and trap thermal desorption extraction. *Journal of Chromatography A*, *1083*(1-2), 146-152.

Topdemir, A., Okutan, T., Kırmızıkaya, G., Yılmaz, P. D. Ö. (2024). Naftalin Asetik Asit, 6-Benzilaminopürin ve İndol-3-Bütirik Asit Kombinasyonlarının Actinidia deliciosa Kallus Gelişimi Üzerine Biyokimyasal Bir Araştırma. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 27*(2), 249-260.

Tosunoğlu, H. (2016). Bursa ilinde satışa sunulmuş balların naftalin kalıntısı yönünden incelenmesi. *Uludağ Arıcılık Dergisi*, *15*(2), 41-46.

Tsimeli, K., Triantis, T. M., Dimotikali, D., & Hiskia, A. (2008). Development of a rapid and sensitive method for the simultaneous determination of 1, 2-dibromoethane, 1, 4-dichlorobenzene and naphthalene residues in honey using HS-SPME coupled with GC–MS. *Analytica chimica acta*, *617*(1-2), 64-71.

Turhan, M., İzol, E. (2023). "Healing Honey and Harmful Pesticides", In 2.International Selçuk Scientific Researches Congress Book p:321-328, October 21-22, Konya, Türkiye.

U.S. EPA. (2021). Health and Environmental Research Online (HERO) Database for Naphthalene. https://hero.epa.gov/hero/index.cfm/project/page/project_id/3064 [accessed 15 March 2021].

Wang, X., Li, X., Li, Z., Zhang, Y., Bai, Y., & Liu, H. (2014). Online coupling of in-tube solid-phase microextraction with direct analysis in real time mass spectrometry for rapid determination of triazine herbicides in water using carbon-nanotubes-incorporated polymer monolith. *Analytical chemistry*, *86*(10), 4739-4747.

Wang, W., Zhang, S., Li, Z., Li, J., Yang, X., Wang, C., & Wang, Z. (2020). Construction of covalent triazine-based frameworks and application to solid phase microextraction of polycyclic aromatic hydrocarbons from honey samples. *Food chemistry*, *322*, 126770.

Yapıcı, İ., İzol, E., Tarhan, A. (2023). "Significant Bioactive Components in Bee Products", In Bee and Bee Products, ed. İzol E., Koçyiğit M., Haspolat Y.K., *Orient Publications,* 1-15.

Yost, E. E., Galizia, A., Kapraun, D. F., Persad, A. S., Vulimiri, S. V., Angrish, M., ... & Druwe, I. L. (2021). Health effects of naphthalene exposure: a systematic evidence map and analysis of potential considerations for dose–response evaluation. *Environmental health perspectives*, *129*(7), 076002.