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Heavy metals concentrations in parsley (*Petroselinum crispum*) vegetable

Maydanoz (*Petroselinum crispum*) Sebzesinde Ağır Metal Konsantrasyonları

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ABSTRACT

With the increase of pollutants in recent years, the environment has been exposed to serious pollution. Heavy metals (HMs) can be considered a potential risk to human health. Furthermore, soil contamination with HMs leads to their transfer to plants and animals and ultimately to humans. Due to their toxic nature, very trace amounts of them can cause serious problems. HMs are one of the important pollutants that are released from various sources. They are very harmful to the environment and health due to their toxicity, stability, and accumulation properties. In this research, the content of HMs in parsley (Petroselinum crispum) has been investigated. For this purpose, HMs such as arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) were investigated in samples collected from local farms in the Tustan region (Lahijan city, Guilan province, Iran). According to the results, all the samples contain HMs above the standard. HMs can cause serious health problems, therefore monitoring food products is very important.

Keywords: Human health, Accumulation, Environmental pollutants, *Petroselinum crispum,* Heavy metals

ÖZ

Son yıllarda kirletici maddelerin artışıyla birlikte çevre ciddi düzeyde kirliliğe maruz kalmıştır. Ağır metaller (AM'ler), insan sağlığı açısından potansiyel bir risk oluşturmaktadır. Ayrıca, toprağın ağır metaller ile kontaminasyonu, bu elementlerin bitkilere ve hayvanlara, dolayısıyla insanlara taşınmasına neden olmaktadır. Toksik özellikleri nedeniyle çok düşük konsantrasyonlarda dahi ciddi sağlık sorunlarına yol açabilmektedirler. Çeşitli kaynaklardan çevreye salınan AM'ler, toksisiteleri, kararlılıkları ve birikim özellikleri nedeniyle hem çevre hem de insan sağlığı üzerinde önemli olumsuz etkiler yaratmaktadır. Bu çalışmada, maydanoz (*Petroselinum crispum*) bitkisinde ağır metal konsantrasyonları incelenmiştir. Bu amaçla, İran'ın Gilan eyaletine bağlı Lahijan şehrinin Tustan bölgesindeki yerel çiftliklerden toplanan örneklerde Arsenik (As), Kadmiyum (Cd), Kurşun (Pb) ve Cıva (Hg) seviyeleri analiz edilmiştir. Elde edilen bulgulara göre, incelenen tüm örneklerde ağır metal seviyeleri belirlenen standart değerlerin üzerinde bulunmuştur. Ağır metallerin ciddi sağlık sorunlarına yol açma potansiyeli göz önünde bulundurulduğunda, gıda ürünlerindeki ağır metal kontaminasyonunun düzenli olarak izlenmesi büyük önem arz etmektedir.

Anahtar Kelimeler: İnsan sağlığı, Birikim, Çevresel Kirleticiler, Maydanoz, Ağır Metaller

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Introduction

Industrialization has brought amazing progress to the world, but at the same time, it has also created many challenges, such as diseases and climate change (Nargis et al., 2022; Nayeem et al., 2023). The impact of many of these problems will be much greater in the future, such as the increase in the rising of the earth's temperature (Guan et al., 2021; Sheydaei et al., 2023). It can be said that economic growth is related to natural resources, therefore, lack of proper management and excessive exploitation cause serious environmental problems (Liu et al., 2023). Among these, the most important issue is human health. It can be said that HMs are a great threat to human health and the environment, and over time, their destructive effects will appear much more (Kolesnikova et al., 2023). Each of them affects the environment differently, but perhaps the most important issue is their bioaccumulation capacity and sustainability (Raj & Maiti, 2019). Figure 1 shows the different ways of absorption by humans and some of their harms. Many things cause the release of HMs, such as coal combustion, steelmaking activity, fertilizers, pesticides, tire wear, brake wear, and fossil fuel combustion (Sheydaei, 2024b).

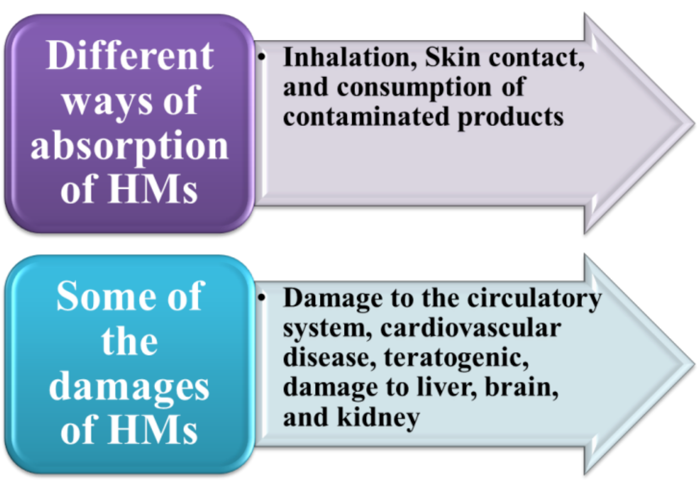

Figure 1.

Different ways of absorption of HMs and some of their damages (El-Amier et al., 2021; Zhu et al., 2022; Zhang et al., 2021).

Figure 2 shows a diagram of pollution of different sources by HMs. As you can see, they have the ability to contaminate almost all sources and easily enter the food chain. It is very important that vegetables are not contaminated because they have a lot of nutrient elements (due to having fiber, vitamins, and antioxidants) (Bahrami et al, 2021). They are also a cheap source of food, so a large group of people eat them.

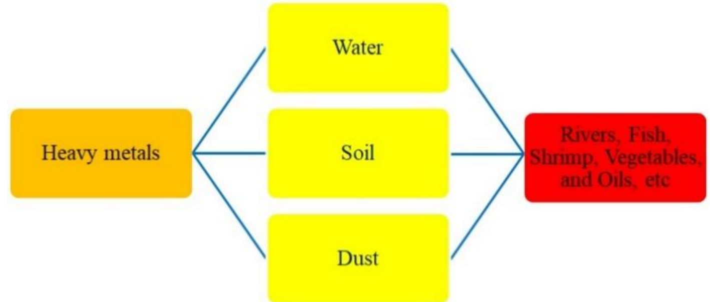

Figure 2.

Contamination of various sources by HMs (Zhu et al., 2022; Zhang et al., 2021).

Among the types of vegetables, parsley (see Figure 3), which belongs to the Apiaceae (Syn. Umbelliferae), the family has been cultivated for more than 2500 years (Marthe 2020). It is mainly used for cooking and garnishing and all parts of the plant can be used (Amein et al., 2006). In northern Iran, local people use parsley extensively in cooking (Ghiasvandnia et al., 2024). Here, parsley was collected from local farms and HMs concentrations were evaluated.

Figure 3.

Parsley (Petroselinum crispum).

Material and Methods

Material

This evaluation focused on local farms in the Tustan region (Guilan province, Iran). Figure 4 shows a map of the area. A total of three farms were sampled. Chemicals were purchased from Ghatran Shimi Tajhiz Co. (Iran).

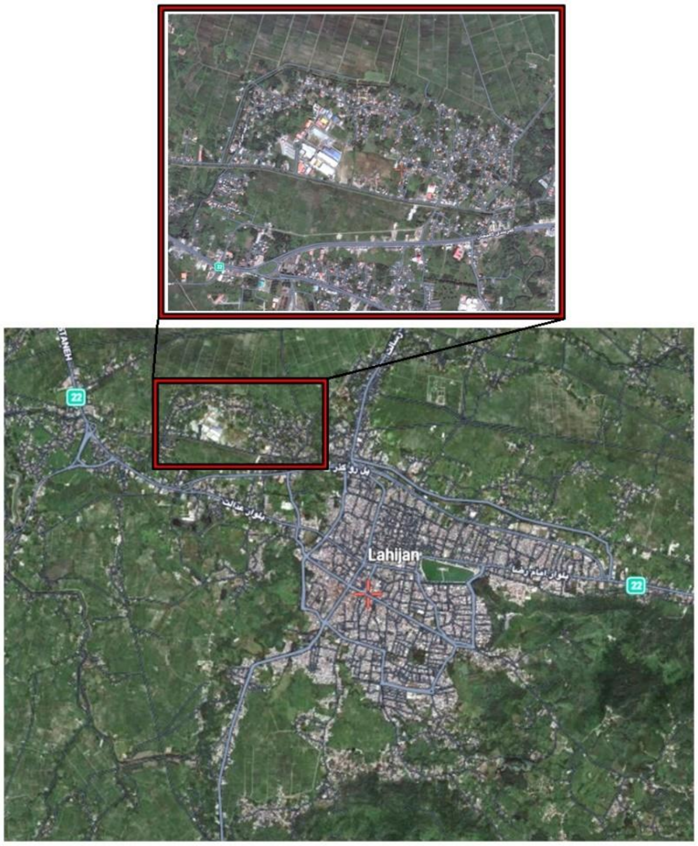

Figure 4.

Tustan region (https://satellites.pro/Iran_map#37.207031,50.004660,14).

Method

The content of HMs was determined on a flame atomic absorption spectrometer (SavantAA, GBC) according to the method described in the literature (Ghiasvandnia et al., 2024; Ghiasvandnia et al., 2023a; Sheydaei et al., 2022; Ghiasvandnia et al., 2023b).

Results and Discussion

Figures 5 and 6 show the region and selected farms of this assessment. The selected area (Tustan) is close to the ring road and the industrial town is also in this area.

Figure 5.

The location of selected farms in the region for investigation (https://satellites.pro/Iran_map#37.224417,49.978995,15).

Figure 6.

The location of the industrial town in the region (https://satellites.pro/Iran_map#37.224373,49.976302,17).

Table 1 shows the evaluation results of HMs in the samples. The results show that all the samples have a high content of HMs, which is higher than the international standards.

Table 1.

HMs concentrations in samples

Metal (mg/kg)	Range	Mean ± SD[d]
Pb	[a]0.4 - 0.51	[a]0.46 ± 0.01
	[b]0.37 -0.48	[b]0.41 ± 0.01
	[c]0.37 - 0.46	[c]0.43 ± 0.01
Cd	[a]0.26 - 0.37	[a]0.33 ± 0.01
	[b]0.26 - 0.32	[b]0.29 ± 0.01
	[c]0.24 - 0.31	[c]0.28 ± 0.01
Hg	[a]0.014 - 0.018	[a]0.015 ± 0.001
	[b]0.01 - 0.013	[b]0.011 ± 0.001
	[c]0.009 - 0.011	[c]0.0096 ± 0.001
As	[a]0.13 - 0.16	[a]0.14 ± 0.01
	[b]0.13 - 0.16	[b]0.14 ± 0.01
	[c]0.09 - 0.11	[c]0.01±0.01

Note: * aSample 1, bSample 2, cSample 3, **SD = Standard deviation *** The international standard for Pb, Cd, Hg, and As is 0.3, 0.2, 0.01, and 0.1, respectively (Ghiasvandnia et al., 2024; Ghiasvandnia et al., 2023a; Ghiasvandnia et al., 2023b; Sheydaei et al., 2022).

The main reason for this high content of HMs is certainly the presence of an industrial town (see Figure 6). Although this area is adjacent to the road, this can be considered as a secondary reason. Definitely, due to the presence of the industrial town, there is a lot of traffic in this area. The pollution of the industrial town has been proven and it should not be located near human settlements (Sheydaei, 2024b; Sheydaei et al., 2022; Ghiasvandnia et al., 2023a; Sheydaei et al., 2020; Sheydaei, 2024a). Wrong policies and decisions damage the confidence of society, the environment, and human health (Sheydaei, 2024b). Each HM has the ability to pollute water, dust, and soil, and vegetables grown in contaminated soil or irrigated with contaminated water contain HMs (Sheydaei, 2024b; Ghiasvandnia et al., 2024; Sheydaei, 2024a]. There is no doubt that the water and soil in this area are also polluted. On the other hand, pollution of sources by cars and some pesticides has also been reported (Ghiasvandnia et al., 2023a; Ghiasvandnia et al., 2023b; Sheydaei, 2024a; Sheydaei, 2024b). In our previous studies, we examined other areas of Lahijan city, and Table 2 compares their results with this study. According to the results, it can be said that Tustan is the most polluted area after Baz Kia Gorab. In northern Iran, local farms located in the surrounding villages are used to produce vegetables (Ghiasvandnia et al., 2024). Therefore, monitoring at all stages of product preparation is very important. Also, the impact of each HM on human health is briefly reported in Table 3.

Table 2.

Results of other studies in Lahijan city

Region	Metal (mg/kg)	Mean
*Baz Kia Gorab	Pb, Cd, Hg, As	1.66, 0.62, 0.046, 0.13
*Kuh Boneh	Pb, Cd, Hg, As	0.1, 0.08, 0.004, 0.03
*Layalestan	Pb, Cd, Hg, As	0.52, 0.29, 0.03, 0.09
*Kushal	Pb, Cd, Hg, As	0.15, 0.076, 0.005, 0.06
This study	Pb, Cd, Hg, As	0.43, 0.3, 0.012, 0.096

Note: * Data was collected from References (Ghiasvandnia et al., 2024; Ghiasvandnia et al., 2023a; Ghiasvandnia et al., 2023b; Sheydaei et al., 2022). Mean values are reported.

Table 3.

The impact of HMs on humans.

HMs	Symptoms and disease
As	Damage to the circulatory system, anti-immune disorder, chronic bronchitis, and damage to liver and kidney.
Cd	Obstructive lung disease, bone defects, negative effect on enzymes, and kidney damage.
Pb	Damage to the brain, damage to the gastrointestinal tract, damage to red blood cells, damage to the reproductive system, and dysfunctions in the kidneys.
Hg	Damage to the lungs, cardiovascular disease, damage to the nervous, and damage to the skin and eyes.

Note: Data was collected from References (Ghiasvandnia et al., 2024; Ghiasvandnia et al., 2023a; Ghiasvandnia et al., 2023b; Sheydaei, 2024a; Sheydaei 2024b).

Conclusion

In summary, the content of HMs in parsley in the Tustan region was investigated. The results showed that all the samples had more HMs than the standard level. HMs can cause serious problems for human health due to their toxicity and bioaccumulation capacity. This study showed that crop monitoring is very important.

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References

Amein, T., Olsson, C. H. B., Wikström, M., Findus, R., Ab, D., & Wright, S. A. I. (2006). First report in Sweden of downy mildew on parsley caused by Plasmopara petroselini. *Plant Disease*, *90*(1), 111-111. https://doi.org/10.1094/PD-90-0111A

Bahrami, S., Moore, F., & Keshavarzi, B. (2021). Evaluation, source apportionment and health risk assessment of heavy metal and polycyclic aromatic hydrocarbons in soil and vegetable of Ahvaz metropolis. *Human and Ecological Risk Assessment: An International Journal*, *27*(1), 71-100. https://doi.org/10.1080/10807039.2019.1692300

El-Amier, Y.A., Elsayed, A., El-Esawi, M.A., Noureldeen, A., Darwish, H., & Fakhry, H. (2021). Optimizing the Biosorption Behavior of Ludwigia stolonifera in the Removal of Lead and Chromium Metal Ions from Synthetic Wastewater. *Sustainability*, *13*, 6390. https://doi.org/10.3390/su13116390

Ghiasvandnia, P., Edraki, M., Shahimi, F., & Sheydaei, M. (2024). Evaluation of concentration of heavy metals and microbial contamination in parsley (Petroselinum crispum) vegetable. *Chemical Research and Technology*, *1*(1), 2-7. https://doi.org/10.2234/chemrestec.2023.181245

Ghiasvandnia, P., Sheydaei, M., & Edraki, M. (2023a). Evaluation of Microbial Contamination and Toxic Metals Content of Parsley (*Petroselinum Crispum*) Obtained in Kuh Boneh Region (Lahijan City, North of Iran). *Asian Journal of Green Chemistry*, *7*(1), 17-24. https://doi.org/10.22034/ajgc.2023.1.3

Ghiasvandnia, P., Sheydaei, M., & Edraki, M. (2023b). Evaluation of toxic metals content and microbial contamination of parsley (Petroselinum crispum) prepared from local farms in Kushal and Layalestan regions (Lahijan city, north of Iran). *Gıda Bilimi ve Mühendisliği Araştırmaları*, *2*(1), 23-27. https://doi.org/10.5152/FSER.2023.1243585

Guan, L., Zhang, W. W., Ahmad, F., & Naqvi, B. (2021). The volatility of natural resource prices and its impact on the economic growth for natural resource-dependent economies: a comparison of oil and gold dependent economies. *Resources Policy*, *72*, 102125. https://doi.org/10.1016/j.resourpol.2021.102125

Kolesnikova, V. M., Salimgareeva, O. A., Ladonin, D. V., Vertyankina, V. Y., & Shelegina, A. S. (2023). Morphological and mineralogical characteristics of atmospheric microparticles and chemical pollution of street dust in the Moscow region. *Atmosphere*, *14*(2), 403. https://doi.org/10.3390/atmos14020403

Liu, G., Chen, T., Cui, J., Zhao, Y., Li, Z., Liang, W., ... & Xiao, T. (2023). Trace Metal (loid) Migration from road dust to local vegetables and tree tissues and the bioaccessibility-based health risk: impacts of vehicle operation-associated emissions. *International Journal of Environmental Research and Public Health*, *20*(3), 2520. https://doi.org/10.3390/ijerph20032520

Marthe, F. (2020). Petroselinum crispum (Mill.) Nyman (Parsley). Medicinal, Aromatic and Stimulant Plants, 435-466. https://doi.org/10.1007/978-3-030-38792-1_13

Nargis, A., Habib, A., Islam, M. N., Chen, K., Sarker, M. S. I., Al-Razee, A. N. M., Liu, W., Liu, G., & Cai, M. (2022). Source identification, contamination status and health risk assessment of heavy metals from road dusts in Dhaka, Bangladesh. *Journal of Environmental Sciences*, *121*, 159-174. https://doi.org/10.1016/j.jes.2021.09.011

Nayeem, A., Ali, M. F., & Shariffuddin, J. H. (2023). The recent development of inverse vulcanized polysulfide as an alternative adsorbent for heavy metal removal in wastewater. *Environmental Research*, *216*, 114306. https://doi.org/10.1016/j.envres.2022.114306

Raj, D., & Maiti, S. K. (2019). Bioaccumulation of potentially toxic elements in tree and vegetable species with associated health and ecological risks: a case study from a thermal power plant, Chandrapura, India. Rendiconti Lincei. *Scienze Fisiche e Naturali*, *30*(3), 649-665. https://doi.org/10.1007/s12210-019-00831-7

Sheydaei, M. (2024a). Heavy metals contamination in soil and rice and their removal processes: a brief review. Geomicrobiology *Journal*, *41*, 721-731. https://doi.org/10.1080/01490451.2024.2388118

Sheydaei, M. (2024b). Investigation of Heavy Metals Pollution and Their Removal Methods: A Review. Geomicrobiology *Journal*, *41*(3), 213-230. https://doi.org/10.1080/01490451.2024.2318227

Sheydaei, M., Alinia-Ahandani, E., & Ghiasvandnia, P. (2020). Cancer and the role of polymer-carriers in drug delivery. *Journal of Genetics and Cell Biology*, *4*, 217-220.

Sheydaei, M., Ghiasvandnia, P., Edraki, M., & Sheidaie, M. (2022). Investigation of toxic metals content of parsley (petroselinum crispum) obtained from local farms in Baz Kia Gorab region (Lahijan city, north of Iran). *Journal of*

Chemistry Letters, *3*(3), 114-118. https://doi.org/10.22034/jchemlett.2023.375932.1096

Sheydaei, M., Pouraman, V., Edraki, M., Alinia-Ahandani, E., & Asadi-Sadeh, S. M. (2023). Targeted application of GO to improve mechanical and thermal properties of PVCS/RS composites. *Phosphorus, Sulfur, and Silicon and the Related Elements*, *198*(4), 345-353. https://doi.org/10.1080/10426507.2022.2150853

Zhu, H., Xu, J., Zhou, B., Ren, J., Yang, Q., Wang, Z., & Nie, W. (2022). Leaching Characteristics of Potentially Toxic Metals from Tailings at Lujiang Alum Mine, China. *International Journal of Environmental Research and Public Health*, *19*, 17063. https://doi.org/10.3390/ijerph192417063

Zhang, C., Zang, X., Dai, Z., Zhang, X., & Ma, Z. (2021). Remediation Techniques for Cadmium-Contaminated Dredged River Sediments after Land Disposal. *Sustainability*, *13*, 6093. https://doi.org/10.3390/su13116093

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Determination of Volatile Compounds in Raw Milk with Mastitis

Mastitisli Sütlerde Uçucu Bileşiklerin Belirlenmesi

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ABSTRACT

Mastitis is a prevalent and economically significant disease in dairy cattle, affecting milk composition and quality. Subclinical mastitis (SCM) is more common and often asymptomatic. It can alter the chemical and cellular composition of milk, making it more difficult to process and potentially affecting the quality of dairy. This study aimed to investigate the volatile compounds present in raw cow's milk using Solid Phase Microextraction (SPME) and Gas Chromatography-Mass Spectrometry (GC-MS). Milk samples were collected from various producers in Çanakkale, Biga and Yenice districts in Türkiye. From these, 10 samples that tested positive in the California Mastitis Test (CMT) were selected for analysis. A total of 49 volatile compounds were determined, including hydrocarbons (9), alcohols (4), aldehydes (3), ketones (7), acids (4), esters (11), terpenes (1), aromatic compounds (5), nitrogenous compounds (1), and other compounds (4). The most prevalent volatile components were butanoic acid, hexanoic acid, octanoic acid, and n-decanoic acid, which contribute to rancid and cheesy flavors in the milk. Other notable compounds detected included acetoin, various ketones, terpenes like d-limonene, and alcohols such as 3-methyl-1-butanol. The presence of these compounds is largely attributed to the metabolic activities of lactic acid bacteria and the degradation of fatty acids. The findings indicate that SCM significantly alters the volatile compound profile of milk, leading to the development of off-flavors that could impact the sensory quality of dairy products. The aim of this study is to provide information about the chemical changes that may occur in raw milk associated with SCM and to emphasize the importance of monitoring milk quality to ensure consumer safety and uphold high standards in dairy product quality.

Keywords: Mastitis, subclinical, CMT test, milk, volatile compound, aroma

ÖZ

Mastitis, süt sığırlarında yaygın olarak görülen ve ekonomik olarak önemli bir hastalıktır ve klinik ve subklinik formlarda ortaya çıkabilir. Subklinik mastitis (SCM), daha sık görülen ve genellikle asemptomatik olan formudur. SCM, sütün kimyasal ve sitolojik bileşiminde değişikliklere yol açarak işleme özelliklerini etkileyebilir ve patojen mikroorganizmalar ve antibiyotik kalıntıları nedeniyle halk sağlığı riskleri oluşturabilir. Bu çalışmada Katı Faz Mikroekstraksiyon (SPME) ve Gaz Kromatografisi-Kütle Spektrometrisi (GC-MS) kullanılarak çiğ inek sütünde bulunan uçucu bileşikler araştırılmıştır. Süt örnekleri, Türkiye'nin Çanakkale iline bağlı Biga ve Yenice ilçelerindeki çeşitli üreticilerden toplanmış ve California Mastitis Testi (CMT) pozitif çıkan 10 örnek analiz için seçilmiştir. Hidrokarbonlar (9), alkoller (4), aldehitler (3), ketonlar (7), asitler (4), esterler (11), terpenler (1), aromatik bileşikler (5), azotlu bileşikler (1) ve diğer bileşikler (4) dahil olmak üzere toplam 49 uçucu bileşeni belirlenmiştir. En baskın uçucu bileşenler, sütte acımsı ve peynirimsi tatlara katkıda bulunan bütanoik asit, hekzanoik asit, oktanoik asit ve n-dekanoik asit olarak belirlenmiştir. Tespit edilen diğer önemli bileşikler arasında asetoin, çeşitli ketonlar, d-limonen gibi terpenler ve 3-metil-1-bütanol gibi alkoller bulunmaktadır. Bu bileşiklerin varlığı büyük ölçüde laktik asit bakterilerinin metabolik aktivitelerine ve yağ asitlerinin parçalanmasına bağlanmıştır. Bulgular, SCM'nin sütün uçucu bileşik profilini önemli ölçüde değiştirdiğini, bu durumun da tat bozulmalarına yol açabileceğini ve süt ürünlerinin duyusal kalitesini potansiyel olarak etkileyebileceğini öne sürmektedir. Bu çalışmanın amacı, SCM ile ilişkili olarak çiğ sütte meydana gelebilecek kimyasal değişiklikler hakkında bilgi sağlamak ve tüketici güvenliğini sağlamak ve süt ürünleri kalitesinde yüksek standartları korumak için süt kalitesinin izlenmesinin önemini vurgulamayı amaçlamaktadır.

Anahtar Kelimeler: Mastitis, subklinik, CMT test, süt, uçucu bileşen, aroma

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Introduction

Mastitis is a significant economic concern in dairy cattle, as it leads to reduced milk production. It can manifest in two forms: clinical and subclinical. Subclinical mastitis (SCM) is characterized by an intramammary infection that does not present any visible clinical symptoms and occurs more frequently than clinical mastitis (Le Maréchal et al., 2011; Ibrahim, 2017; Gonçalves et al., 2018). *Streptococcus agalactiae, Staphylococcus aureus, Streptococcus dysgalactiae, Streptococcus uberis, and Escherichia coli* make up approximately 95% of the microorganisms causing mastitis, with other microorganisms accounting for the remaining 5% (Bray & Shearer, 1994). Several factors can affect the composition of milk, including the animal's breed, age, lactation stage, and diet. Additionally, mastitis can lead to significant changes in the chemical, cytological, and processing properties of milk (Le Maréchal et al., 2011). Milk from animals suffering from mastitis presents a public health concern due to the presence of pathogenic microorganisms and antibiotic residues. Additionally, the presence of antibiotic residues makes this milk unsuitable for further processing (IDF, 2000; Kivaria, 2006; Oliver & Murinda, 2012). Mastitis, an inflammatory reaction of the mammary gland tissue, is a condition with various causes, including infectious, traumatic, or toxic factors (International Dairy Federation (IDF), 1987; Fagiolo & Lai, 2007). However, only if these causes are better known can the condition be effectively predicted, prevented, and managed. When pathogenic microorganisms invade the mammary tissue, they proliferate, causing damage and increasing vascular permeability. The composition of the milk changes as blood components leak into the serum. The proteins, enzymes, and salts in the milk also change; casein and lactose production go down, and ion levels rise (Fagiolo & Lai, 2007; Nielsen, 2009; Leitner et al., 2011; Rovai et al., 2015a; Rovai et al., 2015b). This knowledge inspires hope for a future in which mastitis can be effectively prevented and managed. Moreover, mastitis results in significant economic losses, which include decreased milk production, changes in milk composition, wasted milk, increased costs, additional labor, treatment expenses, and veterinary services. It is estimated that mastitis causes an annual economic loss of $2 billion in the United States, $400 million in Canada, and $130 million in Australia (Aral et al., 2021). The main costs associated with mastitis can be broken down as follows: (1) reduced milk production at approximately $102 per cow, (2) discarded milk costing about $24 per cow, and (3) animal replacement at around $33 per cow. This brings the total cost of mastitis to roughly $159 per cow per year (Dalanezi et al., 2020). In a research study conducted in between 2023 November and 2024 December on endemic diseases in farms with 30 or more head of livestock in Konya (Center) province, Kadınhanı and Sarayönü districts, the economic loss costs for the farm, including treatment processes ($1 is taken as 25 TL), in mild, severe and fatal diseases caused by mastitis were determined as 1300 per cow (total 2550 TL), 2275 per cow (total 4865 TL) and 2600 TL per cow (total 46410 TL), respectively (Özdemir, 2024).

Normal metabolic processes in plant and animal tissues, specific technological processes (such as heating and cooking), and chemical reactions during storage (including photo-oxidation, hydrolysis, and lipid oxidation) can all generate aroma compounds (Reineccius, 2005). The study by Eriksson et al. (2005), which used gas chromatography-mass spectrometry to analyze the volatile compounds in milk samples with mastitis, has practical implications. The study revealed that milk from cows with mastitis contained higher levels of secondary metabolites from bacteria, including sulfides, ketones, amines, and acids. More secondary lipid oxidation products, like saturated and unsaturated aliphatic aldehydes, were in the milk from both healthy reference parts (regions) of the cows with mastitis and healthy cows. This study aimed to investigate the volatile compounds present in raw cow's milk with mastitis using Solid Phase Microextraction (SPME) and Gas Chromatography-Mass Spectrometry (GC-MS), providing valuable insights for or food science and veterinary medicine.

Material and Methods

Material

In our previous study, raw milk samples were collected from 134 milk producers in six villages in Biga and Yenice districts of Çanakkale Province, and the somatic cell counts (SCC) in these samples were measured (Ozdikmenli Tepeli and Zorba, 2017). Based on the SCC results from this study, ten representative raw milk samples with varying SCC values were selected, as shown in Table 1. CMT scores according to Ruegg and Reinemann (2002) are also shown in Table 1. Then, volatile compound analyses of these samples were carried out using Gas Chromatography-Mass Spectrometry (GC-MS).

Table 1.
Somatic cell count (SCC) of the samples

No	Code	CMT score	SCC (cells/mL)
1	N1	Negative-1	46.000
2	N2	Negative-2	53.000
3	N3	Negative-3	99.000
4	T1	Trace-1	364.000
5	T2	Trace-2	373.000
6	T3	Trace-3	332.000
7	M1	1	573.000
8	M2	1	917.000
9	M3	2	2.114.000
10	M4	2	2.527.000

Method

Determination of some physicochemical properties of raw milk

In raw milk samples, pH was measured using the Hanna Combo (HI 98129, USA) device, DN was measured using the Funke Gerber-Cryostar (Gerber, Germany) device, and fat, lactose, protein, and non-fat dry matter (NFDM) ratios were measured using the Funke Gerber-3560 Lactostar (Gerber, Germany) device.

Volatile compounds analysis of raw milk

Three milliliters of each raw milk sample were weighed and transferred into amber bottles. After that, 1 g of NaCl and 5 µL of Internal Standard (20 µl of 2-methyl valeric acid and 5 µl of 2-methyl 3-heptanone in 5 mL of methyl alcohol) were added to a 40 mL volume vial and mixed with vortex for 15 seconds. They incubated at in a 40°C water bath (GFL, Model 1103, Burgwedel, Germany), for 20 minutes to allow the volatiles in the headspace to equilibrate. The solid phase microextraction (SPME) fiber (2 cm, 50/30 µm DVB/Carboxen/PDMS StableFlex, Supelco, Bellefonte, USA) was then inserted into the vial and left in a 40°C water bath for 15 minutes to absorb the aroma components in the headspace. Gas chromatography is equipped with a flame ionization detector (FID) and a CIS-Cooled Injection System (CIS) injection block (Agilent 6890N, Palo Alto, California, USA). All samples were injected into a polar (HP-INNOWAX, 30 mm length×0.25 mm inner diameter (i.d.)×0.25 µm film thickness; J&W Scientific) belt. The GC-MS column temperature program was at 40°C initial temperature held for 5 min, and is adjusted to reach the final temperature of 230°C with 10°C increments per min. The temperature of the injector block reached at 230°C. The waiting time at the final temperature was set to 15 min. Total analysis time was 54 min (Guneser & Karagul-Yuceer, 2011). Identification of the volatile components was performed using the Wiley Registry of Mass Spectral Data (Wiley, 2005) and the National Institute of Standards and Technology (NIST, 2008)

Statistical analysis

In order to statistically evaluate the volatile component analysis results of mastitis raw milk samples, the SPSS 22 (SPSS 2022) statistical program was used, and descriptive statistical analyses were performed. The results are given as mean and standard error. Analyses were performed in 2 replications.

Results and Discussion

Some physicochemical properties of samples with different SCC values are shown in Table 2. Although a decrease in protein value was observed as SCC values increased, many values remained within the reference limits.

Table 2.
Some physicochemical properties of raw milk samples

No		pH	Fat %	Protein %	NFDM %	Lactose %
	*Referans value**	*6.60-6.80**	*2.5-6.0**	*2.9-5.0**	*min 8.5**	*3.6-5.5**
1	N1	6.79	2.60	1.99	6.36	3.97
2	N2	6.98	3.28	2.45	7.43	4.58
3	N3	7.08	3.69	3.38	8.52	4.81
4	T1	7.06	3.42	2.73	7.58	4.49
5	T2	6.86	3.55	3.00	7.99	4.64
6	T3	6.83	3.60	3.20	8.15	4.66
7	M1	6.91	4.00	3.08	7.86	4.44
8	M2	6.74	3.58	2.69	7.52	4.51
9	M3	7.12	3.35	2.93	7.53	4.24
10	M4	6.84	3.31	2.90	7.87	4.60

*Anonim 2000, 2006, 2009 and Metin 2005. The samples are listed in ascending order according to their SCC values. NFDM: Non-fat dry matter

The analysis revealed that the following chemical groups comprised 51 identified compounds. These groups include hydrocarbons, alcohols, aldehydes, ketones, acids, esters, terpenes, and aromatic compounds. Some of these volatile compounds include ethyl alcohol, acetoin, hexane, acetic acid (vinegar), ethyl acetate, 3-hydroxy-2-butanone (sour milk), and 3-methyl-1-butanol (fresh cheese, breathtaking, and alcoholic). The volatile compounds include butanoic acid ethyl ester, hexamethyl cyclotrisiloxane, butanoic acid (butter, cheese, sweat, acid), 3-methyl butanoic acid (sweaty, bitter, cheese, rancid), 2-methyl butanoic acid, 2,2,4,6,6-pentamethylheptane, hexanoic acid ethyl ester, hexanoic acid (sweaty, cheese, goat), d-limonene (lemon, mint), 2-nonanone (flower, fruit, peach), 2,6,10,14-phenyl ethanol (rose, flower). In general, compared to other volatile compounds, mastitis milk samples had relatively higher contents of acids such as acetic acid (vinegar), butanoic acid (cheesy), 3-methyl butanoic acid (sweaty, bitter, cheese, rancid), and hexanoic acid (sweaty, cheesy, goat). Among all volatile components, butanoic acid, hexanoic acid, octanoic acid, and n-decanoic acid were the most dominant. Butanoic acid (3583.13 μg/kg), hexanoic acid (3724.07 μg/kg), and octanoic acid (10896.32 μg/kg) were all highest in the N3 milk sample. On the other hand, butanoic acid (221.08 μg/kg) and hexanoic acid (377.64 μg/kg) were lowest in the M3 and T2 milk samples (Table 1). Lipolysis, the breakdown of lactose and amino acids, produces acids that give milk its perceivable rancid flavor. Carboxylic acids are not only vital volatile components in milk, but they are also key precursors of other compounds such as methyl ketones, alcohols, aldehydes, and esters (Yeu et al., 2015).

Milk samples with mastitis also contained aldehydes, such as hexanal, three methyl butanal, and pentanal (Table 3). Aldehydes are temporary compounds that can be formed during transamination or Strecker degradation during the catabolism of amino acids. Amino acids are converted to α-keto acids and then to aldehydes by the action of the aminotransferase enzyme. However, they are converted to alcohols and acids after a short time. Some aldehydes (such as butanal, pentanal, hexanal, octanal) are not formed during the catabolism of amino acids but by the β-oxidation of unsaturated fatty acids (Avşar et al., 2011). The Strecker metabolic pathways of lactic acid bacteria generate these compounds by decarboxylating branched-chain keto acids. Secondary oxidation of unsaturated fatty acids can also create them (Demirkol et al., 2016; Tahmas-Kahyaoglu et al., 2022). Oleic acid oxidation may generate hexanal, a well-known secondary oxidation product of linoleic acid. These compounds are responsible for the off-flavor found in milk and dairy products (Demirkol et al., 2016). The present study detected d-limonene, one of the terpenes, in different concentrations in the milk samples. However, the present study only detected this compound in four samples (N1, K5, T3, M3). The amount of d-limonene in the milk samples ranged from 0.99 to 3.04 μg/kg. Terpenes are compounds of plant origin that can pass into milk and from milk into products through grazing of dairy animals (Avşar et al., 2011). Plants naturally transfer terpenes and sesquiterpenes from forage plants to dairy products (Demirkol et al., 2016; Akgul et al., 2020; Guneser and Aydin, 2022). Further, they are crucial in determining the geographical origin (Akgul et al., 2020). Low concentrations of ketones can produce characteristic odors such as fruity, flowery, and musty. Furthermore, ketones like 2-nonanone and 2-undecanone are well-known to contribute to the aroma of dairy products (Akgul et al., 2020). Ketones are formed as β-keto acids (β-ketoacyl-coenzyme A.) after the conversion of triglycerides to free fatty acids by lipase enzyme, especially by the action of fungal (*Penicilium roqueforti*, *Penicilium camemberti* and *Geotrichum candidum*) or bacterial (*Lactococcus lactis*) enzymes. Methyl ketones are formed as a result of the decarboxylation of β-keto acids. Methyl ketones are converted to secondary alcohols by the action of lactic acid bacteria (*Lactobacillus* spp., *Leuconostoc* spp.). The formation of ketones such as diacetyl (2,3-butanedione) and acetoin (3-hydroxy-2-butanone) is not caused by fatty acids, but occurs by the breakdown of pyruvate formed as a result of lactose and citrate degradation (Avşar et al., 2011).

The study also found ketones in the subclinical mastitis milk samples. These included 2-nonanone, which smells like dirty milk, 2-heptanone, which tastes like cheese and wax, 2-butanone, and 2-undecanone, which tastes like citrus, wax, and cream. All samples detected 2-butanone among the ketones, while some failed to detect others. So, the N3 sample had higher amounts of 2-heptanone and 2-heptanone-24.34 μg/kg than the other milk samples (Table 3). Methyl ketones are made when fatty acids are oxidized, and β-keto acids made from saturated fatty acids are decarboxylated (Guneser & Aydin, 2022).

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Table 3. presents the volatile compound profile of raw milk samples with different SCC values, as determined by the precise and reliable method of SPME-GC-MS.

Table 3.

Volatile compound profile of mastitis raw milk samples determined by GC-MS (µg/kg)

Volatile Compounds	RI	Samples (Average±std. Error)									
		N1	N2	N3	T1	T2	T3	M1	M2	M3	M4
Alcohols											
Phenyl ethyl alcohol	<500	Nd.	Nd.	Nd.	4.49±0.12	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
3-Methyl-1-Butanol	751.61	19.83±3.69	Nd.	Nd.	Nd.	5.50±0.44	Nd.	Nd.	Nd.	Nd.	Nd.
2-Ethyl-1-hexanol	1031.49	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	2.38±0.18	Nd.
Dimethyl silanediol	690.92	6.93±0.00	Nd.	8.41±2.94	4.38±0.46	6.36±0.11	3.75±0.13	Nd.	Nd.	12.42±0.00	Nd.
Esters											
Ethyl Acetate	613.43	22.36±3.28	49.41±0.70	35.42±1.63	Nd.	38.92±0.57	1.85±0.62	8.34±3.88	3.63±0.18	6.27±0.02	Nd.
Ethyle ester formic acid	611.64	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
Methyl ester butanoic acid	718.35	Nd.	1.97±0.22	14.99±5.35	0.37±0.25	Nd.	Nd.	Nd.	1.27±0.41	Nd.	1.67±0.17
Ethyl ester butanoic acid	801.83	Nd.	36.07±2.73	50.13±17.02	1.31±0.34	Nd.	Nd.	4.51±0.77	Nd.	2.35±0.07	Nd.
Ethyl ester hexanoic acid	999.81	Nd.	22.54±3.39	22.00±13.75	Nd.	Nd.	Nd.	1.15±0.15	Nd.	2.94±0.25	Nd.
Ethyl ester decanoic acid	1394.87	Nd.	Nd.	0.81±0.33	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
Methyl ester octanoic acid	1124.16	Nd.	Nd.	6.46±2.43	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
3-ethoxy-ethyl ester-2-propenoic acid	1150.28	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	2.43±0.19
4-trimethylsilyl ester benzoic acid	1161.94	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	2.13±0.47
Ethyl ester octanoic acid	1198.66	Nd.	Nd.	Nd.	0.64±0.06	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
Methyl ester decanoic acid	1321.62	Nd.	Nd.	1.32±0.54	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
Aldehydes											
3-Methyl-Butanal	645.91	12.27±0.00	1.75±0.02	1.57±0.50	Nd.	1.73±0.00	Nd.	1.77±0.00	1.07±0.06	Nd.	Nd.
Hexanal	798.86	Nd.	Nd.	Nd.	0.67±0.17	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
Pentanal	645.78	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	nd.	1.29±0.01	Nd.
Hydrocarbons											
Hexane	603.81	Nd.	Nd.	Nd.	Nd.	Nd.	1.91±0.35	Nd.	Nd.	Nd.	Nd.
Propane	652.69	Nd.	Nd.	Nd.	0.82±0.02	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.
2.4-Dimethyl heptane	819.31		2.08±0.01	1.22±0.22	1.57±0.61	2.74±0.11	1.39±0.43	1.08±0.12	2.71±0.41	0.77±0.04	2.57±0.31
Decane	1000.16	Nd.	Nd.	Nd.	Nd.	Nd.	3.39±0.36	Nd.	Nd.	Nd.	Nd.
4-methyl-octane	860.22	Nd.	1.58±0.02	0.93±0.14	Nd.	2.97±0.22	1.49±0.33	1.36±0.09	2.39±0.39	Nd.	2.35±0.12
4-methyl-decane	1022.49	2.10±0.14	Nd.	Nd.	Nd.	2.73±0.01	Nd.	Nd.	Nd.	Nd.	1.27±0.23
2.6-dimethyl-nonane	1022.71	Nd.	Nd.	Nd.	1.52±0.57	Nd.	1.56±0.35	Nd.	Nd.	Nd.	Nd.
3.4-dimethyl-decane	1060.18	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	0.89±0.06
3.6-dimethyl- decane	1102.29	Nd.	Nd.	Nd.	2.37±0.91	Nd.	9.05±6.71	1.67±0.03	1.34±0.17	Nd.	Nd.

Nd: Not Detected

Table 3.
Continued

Ketones	RI	Samples (Average±std. Error)									
3-methyl-2-butanone	69..28	1.70±0.13	10.95±1.13	2.96±0.81	0.96±0.14	2.42±0.11	0.93±0.16	1.61±0.01	1.49±0.01	1.51±0.06	7.82±0.99
3-hydroxy-2-butanone	606.28	6.72±1.22	Nd.	Nd.	Nd.	5.37±0.09	Nd.	Nd.	Nd.	Nd.	Nd.
Acetoin	<500	Nd.	57.15±7.45	17.28±6.50	80.75±18.69	65.76±1.72	7.59±0.55	79.17±13.62	35.94±4.05	Nd.	64.62±0.85
2-Butanone	600.26	1.70±0.13	22.54±3.39	25.69±10.06	0.98±0.14	2.42±0.11	0.93±0.15	1.15±0.15	1.49±0.00	2.94±0.25	4.53±0.15
2-Heptanone	887.64	2.61±0.26	21.41±1.18	24.34±8.68	Nd.	13.80±1.43	27.21±5.65	4.13±0.68	3.34±0.26	Nd.	3.61±0.01
2-Nonanone	1090.30	1.91±0.06	6.72±0.89	9.17±3.27	Nd.	14.23±0.45	27.97±7.06	0.93±0.01	1.49±0.61	Nd.	Nd.
2-undecanoate	1292.15	Nd.	1.08±0.07	2.19±0.21	Nd.	Nd.	0.31±0.19	Nd.	Nd.	Nd.	Nd.
Aromatic compounds											
Methyl benzene	759.83	Nd.	Nd.	3.54±1.17	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	12.09±0.53
Toluene	760.25	1.84±0.34	8.72±0.32	Nd	6.27±1.04	9.29±0.58	6.74±1.07	5.64±0.69	16.59±2.67	5.99±0.31	
1.2.3.4-tetramethyl-benzene	1111.74	1.83±0.13	1.46±0.01	1.16±0.19	0.28±0.02	1.78±0.01	0.62±0.08	1.36±0.08	1.22±0.24	1.35±0.08	0.41±0.02
1-ethyle.2.3-dimethyl benzene	1115.63	Nd.	Nd.	Nd.	0.28±0.02	0.50±0.16	Nd.	Nd.	0.32±0.01	Nd.	1.59±0.05
1.2-dichloro-benzene	1004.94	Nd.	Nd.	Nd.	2.38±0.70	Nd.	Nd.	Nd.	Nd.	Nd.	6.02±0.30
Acids											
Butanoic acid	797.79	319.68±7.02	521.13±231.31	3583.13±13.5	234.74±22.30	267.20±7.80	Nd.	959.15±151.03	613.29±20.37	221.08±36.29	1430.35±71.09
Hexanoic acid	1002.97	1168.50±117.74	2305.04±331.01	3724.07±84.66	663.80±91.53	377.64±9.68	Nd.	2151.33±300	1880.63±88.64	692.90±41.62	2996.64±8.66
Octanoic acid	1184.70	Nd.	3335.32±20.63	10896.32±658.51	Nd.	Nd.	Nd.	764.16±30.47	860.48±147.95	Nd.	2131.49±287.93
n-Decanoic acid	1369.28	Nd.	543.47±39.08	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	Nd.	432.02±123.64
Terpenes											
dl-Limonene	102..76	2.20±0.01	Nd.	Nd.	1.52±0.57	Nd.	3.04±0.51	Nd.	Nd.	0.99±0.16	Nd.
Other compounds											
1.1.2.2-tetrachloro ethane	909.05	Nd.	Nd.	Nd.	0.47±0.18	Nd.	0.61±0.11	Nd.	Nd.	Nd.	Nd.
Tetrachloroethylene	806.98	7.99±0.26	18.93±1.6	Nd.	15.98±2.29	24.08±1.55	13.90±2.61	17.19±2.60	29.19±4.04	14.87±0.23	28.95±1.22
Hexamethyl-cyclotrisiloxane	822.19	3.96±0.53	7.53±1.32	Nd.	4.11±0.48	5.63±0.12	3.63±0.06	4.79±0.76	4.85±0.48	6.03±0.27	Nd.
Octamethyl-cyclotetrasiloxane	1005.05	Nd.	Nd.	Nd.	3.91±0.44	5.18±0.17	3.83±0.14	5.88±1.23	3.94±0.18	5.59±0.52	Nd.
Nitrogenous compound											
Methoxy-phenyl oxime-	910.95	3.39±0.43	4.37±0.71	3.87±1.44	3.25±0.21	3.86±0.04	3.39±0.08	3.54±0.45	2.99±0.49	Nd.	5.99±0.81

Nd: Not dedected

Methyl ketones are made when fatty acids are oxidized, and β-keto acids made from saturated fatty acids are decarboxylated (Guneser & Aydin, 2022). Acetoin, responsible for the creamy flavor and sweet taste of dairy products, is derived from the fermentation of lactose. All milk samples (except for N1 and M3) contained compounds, albeit in varying quantities. The T1 sample had the highest amount of acetoin (80.75 g/kg), while the T3 sample had the lowest amount (7.59 g/kg) (Table 3). When homo/heterofermentative lactic acid bacteria break down citrate and lactose, they produce acetoin, a volatile compound (Guneser & Aydin, 2022). Moreover, lactic acid bacteria use α-acetolactate synthase and α-acetolactate decarboxylase enzymes in lactose or citrate metabolism to create acetoin (Demirkol et al., 2016).

Alcohols are formed through various metabolic processes, including amino acid metabolism, lactose metabolism, methyl ketones reduction, and degradation of unsaturated fatty acids. They can also be converted into ethyl alcohol by heterofermentative microorganisms, acetaldehyde, and 8-carbon unsaturated alcohols. Deamination events, influenced by oxido-reductases, are also involved in the formation of alcohols from amino acids. *Geotrichum candidum*, rich in oxido-reductases, can convert amino acids into alcohol compounds like ethanol, 2-methylpropanol, 3-methyl-butanol, and phenyl alcohol. (Avşar et al., 2011). Subclinical mastitis-affected milk samples contained alcohols such as phenylethyl alcohol, 3-methyl-1-butanol, 2-ethyl-1-hexanol, and dimethyl silanediol (Table 3). Furthermore, only phenylethyl alcohol and 2-ethyl-1-hexanol were detected in samples T1 and M3, respectively. Many metabolic pathways in dairy products produce alcohol, including lactose metabolism, methyl ketone degradation, and amino acid metabolism. Furthermore, the native milk flora significantly contributes to alcohol formation in dairy products. Even though ethanol is a precursor of ethyl esters, it only has a minor aromatic function in dairy products. Furthermore, milk widely accepts branched-chain alcohols like 3-methyl-2-butanol as off-flavoring components. This is thought to be due to the conversion of reactive aldehydes into alcohol or acid components (Akgul et al., 2020).

Esters are formed as a result of lactose fermentation and/or amino acid catabolism and alcohol (primary and secondary) that will participate in the reaction, and ester compounds are formed as a result of the esterification reaction of acid and alcohol in equal molar volumes. In addition, acidolysis and transesterification reactions play a role in the modification of esters (Avşar et al., 2011). Esters are flavor-enhancing compounds present in fermented milk. Although they contribute positively to flavor balance at low concentrations, at high concentrations, they can cause fruity taste defects (Akgul et al., 2020; Tahmas-Kahyaoglu et al., 2022). Moreover, high ethyl esters of long-chain fatty acids (C12 or above) might give the product an unpleasant, soapy, tallowy odor (Akgul et al., 2020). Eleven different ester compounds were detected in milk samples (Table 3). While multiple samples detected ethyl acetate, methyl ester butanoic acid, ethyl ester butanoic acid, and ethyl ester hexanoic acid, only one sample detected each other. Hydrocarbons, which are secondary products of lipid oxidation, directly influence scent; they also contribute to the formation of other aroma components. Low concentrations of hydrocarbons were detected in all milk samples. While multiple samples detected 2,4-dimethylheptane, 4-methyloctane, and 4-methyldecane, only one sample detected each of the other compounds. Each milk sample contained aromatic compounds, even at low concentrations. Except for samples M4 and N3, low amounts of toluene were detected. This compound may have originated from carotenoid degradation or solvent contamination (Cakmakci & Hayaloglu, 2011).

Other researchers (Mounchili et al., 2005; Eriksson et al., 2005) have also identified some of these volatile compounds in raw milk samples from cows with mastitis. Eriksson et al. (2005) identified 103 volatile compounds in milk samples suffering from mastitis. The researchers found that milk samples from cows with mastitis contained higher levels of sulfur, ketones, amines, and acids. The main parts found by researchers were ethanol, trimethylamine, 2,3-butanedione, 2-pentanone, 2-methylbutanal, methane-thiol, dimethylsulfide, and acetic acid compounds. They found that milk samples from healthy individuals contained more secondary lipid oxidation products, particularly homologous saturated and unsaturated aldehydes, than those from individuals with mastitis. In particular, the researchers linked samples containing higher levels of pentanal with reference milk samples. Researchers found that milk samples from healthy cows had higher levels of typical secondary lipid oxidation products and C4-C8 alcohols compared to milk with mastitis. Mounchili et al. (2005) first analyzed milk samples from 9 Holstein cows organoleptically using two sensory panelists, mass spectrometry/flame ionization (MSD/FFID), and olfactometric detectors. The analysis revealed 75 volatile compounds. Butane-2,3-dimethyl, pentane-3-methyl, acetic acid ethyl ester, heptane, hexane-2,5-dimethyl, hexane-2,4-dimethyl, pentane-2,3, 3-trimethyl, hexane-2,3-dimethyl, 4-methyl heptane-, 3-methyl-heptane, octane, 2-ethyl-dodecane-, ethyl benzene, 1,3-dimethyl benzene, hexanoic acid, limonene, nonanal, undecane, octanoic acid, benzoic acid, ethyl ester, benzaldehyde ethyl, undecane-2-one, and decanoic acid were some of the parts that researchers found.

Comparative analysis with previous studies, such as those by Eriksson et al. (2005) and Mounchili et al. (2005), supports the observation that milk from animals with mastitis tends to have elevated levels of compounds, including sulfur, ketones, amines, and acids, which negatively affect the sensory qualities of the milk. These compounds are often the result of microbial activity, lipid oxidation, and other metabolic processes triggered by the mastitis infection.

Conclusion and Recommendations

In conclusion, the use of solid-phase microextraction (SPME) coupled with gas chromatography-mass spectrometry (GC-MS) to analyze raw milk samples from animals with subclinical mastitis (SCM) revealed the presence of a wide range of volatile compounds. The 51 compounds identified were divided into various chemical groups, including hydrocarbons, alcohols, aldehydes, ketones, acids, esters, terpenes, and aromatic compounds. The results show that milk samples from cows with mastitis contained higher amounts of volatile acids, including butanoic acid, hexanoic acid, octanoic acid, and decanoic acid. These acids are associated with unpleasant odors, such as rotten, cheesy, and sweaty smells.

Additionally, aldehydes and ketones, particularly hexanal, 3-methylbutanal, and 2-heptanone, were detected as contributing to taste disturbances. Though in lower concentrations, terpenes such as d-limonene highlight the influence of forage plants on the milk's volatile profile. Alcohols and esters have also been found to have different effects on flavor depending on their concentration. Overall, mastitis, an inflammation of the mammary gland in dairy cattle, is a significant challenge for the dairy industry worldwide. It affects milk production, quality, and safety, while also imposing substantial economic burdens on milk producers. Early detection of mastitis is critical for maintaining milk safety, reducing economic losses, and ensuring animal welfare. Particularly in its subclinical form, it can compromise milk safety by introducing pathogenic bacteria into the milk supply. Moreover, these volatile compounds compromise the sensory qualities of milk and suggest potential health risks associated with consuming milk from animals with subclinical mastitis. This underscores the importance of early detection and management of mastitis to ensure the safety and quality of dairy products.

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References

Anonim. (2000). *Türk Gıda Kodeksi Çiğ süt ve ısıl işlem görmüş içme sütleri tebliği*. Resmi Gazete, 14 Şubat 2000-Sayı: 23964.

Anonim. (2006). *Türk Gıda Kodeksi Çiğ süt ve ısıl işlem görmüş içme sütleri tebliğinde değişiklik yapılması hakkında tebliğ*, Sayı 26267, Tebliğ No: 2006/38.

Anonim. (2009). *Türk Gıda Kodeksi Çiğ süt ve ısıl işlem görmüş içme sütleri tebliğinde değişiklik yapılması hakkında tebliğ*, Sayı 27133, Tebliğ No 2009/14.

Akgul, F.Y., Ceylan, H.G. & Atasoy, A.F. (2020). Determination of fatty acids profiles and volatile compounds of cows' and goats' butter. *International Journal of Agriculture*, *Environment and Food Sciences*, *4*(1), 7-13.

Aral, Y., Ulutas, Z., Tekin, M.E. & Mamak, N. (2021). Economic losses from clinical mastitis in dairy cows. *Veterinary Journal*, *25*(2), 145-152.

Avşar Y.K., Karagül-Yüceer Y. & Hayaloğlu, A.A. (2011). *Peynir Biliminin Temelleri*. A.A. Hayaloğlu & B. Özer (Eds). Peynirde aroma (272-283s). Sidas Medya Ltd. Şti.

Bray, D.R., & Shearer, J.K. (1994). *Mastitis control programs: Bovine mastitis and milking management*. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Cakmakci, S., & Hayaloglu, A.A. (2011). Volatile components and free fatty acid profiles of traditional and industrially produced Turkish White brined cheese. *Food Chemistry*, *124*(2), 717-726.

Dalanezi, F.M., Joaquim, S.F., Guimarães, F.F., Guerra, S.T., Lopes, B.C., Schmidt, E.M. S., & Langoni, H. (2020). Influence of pathogens causing clinical mastitis on reproductive performance of dairy cows. *Journal of Dairy Science*, *103*(5), 3645-3654.

Demirkol, O., Hayaloglu, A.A., & Cakmakci, S. (2016). Volatile profiles and sensory characteristics of white-brined Urfa cheese made with raw and pasteurized cows' milk during ripening. *LWT - Food Science and Technology*, *65*, 260-266.

Eriksson, T., Folkesson, M., Jonsson, P., & Jansson, J.K. (2005). Comparative metaproteomics of bacterioplankton from three Baltic Sea sites. *ISME Journal*, *4*, 17–28.

Fagiolo, A., & Lai, O. (2007). Mastitis in buffalo. *Italian Journal of Animal Science, 6*(Suppl 1), 200-206.

Gonçalves, J.L., Kamphuis, C., Martins, C.M., Barreiro, J.R., & Tomazi, T. (2018). Bovine subclinical mastitis reduces milk yield and economic returns. *Journal of Dairy Science*, *101*(4), 3685-3697.

Guneser, B.A., & Aydın, A. (2022). Volatile and sensory characterization of fresh and ripened cheese varieties. *Journal of Food Processing and Preservation*, *46*(4), e15953.

Guneser O., & Yuceer Y. (2011). Characterization of aroma-active compounds, chemical and sensory properties of acid-coagulated cheese: Circassian cheese. *International Journal Of Dairy Technology*, *64* (4), 517-525.

Ibrahim, H.M. (2017). Mastitis in dairy cows. *Journal of Veterinary Medicine and Animal Health*, *9*(4), 66-72.

International Dairy Federation (IDF). (1987). Bovine mastitis: Definition and guidelines for diagnosis. Intl. Dairy Fed. Bull. No: 211, Intl. Dairy Fed., Brussels, Belgium.

International Dairy Federation (IDF). (2000). *Suggested interpretation of mastitis terminology*. Intl. Dairy Fed. Bull. No: 345, Intl. Dairy Fed., Brussels, Belgium.

Kivaria, F.M. (2006). Epidemiological studies on bovine mastitis in smallholder dairy herds in the Dar es Salaam region, Tanzania. *Journal of Veterinary Science*, *7*(4), 339-344.

Le Maréchal, C., Thiéry, R., Vautor, E., & Le Loir, Y. (2011). Mastitis impact on milk production and quality in dairy cows. *Animal Health Research Reviews*, *12*(2), 216-234.

Leitner, G., Merin, U., & Silanikove, N. (2011). Changes in milk composition are affected by subclinical mastitis in goats. *Journal of Dairy Science*, *94*(6), 2667-2672.

Metin, M. (2005). *Süt Teknolojisi, Sütün Bileşimi ve İşlenmesi*. Ege Üniversitesi Basımevi, Bornova-İzmir,439s.

Mounchili, A., Scholl, D. T., Cue, R. I., Stryhn, H., & Wichtel, J.J. (2005). Effect of subclinical mastitis on the production of dairy cows. *Journal of Dairy Science*, *88*(5), 2096-2101.

Nielsen, C. (2009). The economic impact of mastitis in dairy cattle herds. *Food Economics*, *6*(2), 181-194.

NIST. (2008). *NIST-/EPA-/NIH Mass Spectral Library (NIST 08)*. National Institute of Standards and Technology Standard Reference Data Program, Gaithersburg, MD 20899.

Oliver, S.P., & Murinda, S.E. (2012). Antimicrobial resistance of mastitis pathogens. *Veterinary Clinics of North America: Food Animal Practice*, *28*(2), 165-185.

Ozdikmenli Tepeli S., & Zorba N.N. (2017). Çanakkale (Yenice) ilinde üretilen çiğ sütlerin bazı özellikleri ve subklinik (gizli) mastitis görülme oranı. *Trakya University Journal of Natural Sciences*, *18*(1), 41-47.

Özdemir H.H. (2024). *Research on the economic importance of some selected animal diseases and the level of knowledge of producers in Kadınhanı and Sarayönü districts of Konya province*. Selçuk University Institute of Health Sciences, Konya, Türkiye. 109p.

Reineccius, G. (2005). *The Flavor Chemistry and Technology*. 2nd Edn. CRC Press., Boca Raton, Florida, USA.

Rovai, M., Llach, I., & Penry, J. (2015a). The effect of intramammary infection on milk production and composition. *Journal of Dairy Research*, *82*(4), 350-358.

Rovai, M., Urban-Chmiel, R., & Wernicki, A. (2015b). Effect of mastitis on milk composition and the presence of microorganisms in cow's milk. *Medicina Veterinaria*, *71*(12), 650-656.

Ruegg, P. L., & Reinemann, D. J. (2002). Milk quality and mastitis tests. *The Bovine Practitioner*, 41-54.

Tahmas-Kahyaoglu, D., Kilic-Akyilmaz, M., & Simsek, S. (2022). Some dairy products' sensory, volatile, and texture profiles are produced using traditional methods. *LWT - Food Science and Technology*, *156*, 113070.

Wiley. (2005). Wiley Registry of Mass Spectral Data 7. Edition (Fred. W. McLafferty) ISBN: 978-0471473251, (CD-ROM).

Yeu, K., Lee, J., & Kang, S. (2015). Detection of volatile compounds in raw and pasteurized milk using headspace solid-phase microextraction gas chromatography-mass spectrometry. *Food Science and Biotechnology*, *24*(6), 1987-1994.

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Sumak (*Rhus coriaria* L.) Bitkisinin Biyoaktif Bileşikleri, Etkileri ve Kullanım Alanları

Bioactive Compounds, Effects and Uses of Sumac (*Rhus coriaria* L.) Plant

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ÖZ

Sumak (*Rhus coriaria* L.), geleneksel ve modern kullanımlarıyla dikkat çeken, biyoaktif bileşenler açısından zengin bir bitki türüdür. Polifenoller, flavonoitler, tanenler ve uçucu yağlar gibi bileşenleri sayesinde antioksidan, antimikrobiyal, antienflamatuvar, antikanser ve antidiyabetik gibi çok çeşitli biyolojik aktivitelere sahiptir. Bu özellikler, sumak bitkisini gıda, sağlık, kozmetik ve ilaç gibi farklı endüstrilerde önemli bir doğal kaynak haline getirmiştir. Sumak, gıda endüstrisinde doğal koruyucu ve renk verici olarak kullanılmakta, antimikrobiyal etkileriyle gıda güvenliğini artırmakta ve raf ömrünü uzatmaktadır. Kozmetik sektöründe ise cilt sağlığını destekleyen ürünlerin formülasyonlarında yer almakta, farmakolojik açıdan çeşitli hastalıkların önlenmesi ve tedavisinde yardımcı olabileceği düşünülmektedir. Ayrıca, tarım ve çevre uygulamalarında da potansiyel faydaları araştırılmaktadır. Bu derleme çalışmasında, sumak bitkisinin kimyasal bileşimi, biyolojik etkileri ve sağlık üzerindeki faydaları detaylı bir şekilde ele alınmaktadır. Bunun yanı sıra, bitkinin farklı endüstriyel kullanım alanları incelenmekte ve sürdürülebilir üretim yöntemleri ile ilgili zorluklar tartışılmaktadır. Çalışmanın amacı, sumak bitkisinin biyoaktif bileşiklerinin çok yönlü etkilerini ve uygulama potansiyellerini ortaya koyarak bilimsel bilgi birikimine katkı sağlamaktır. Bu bağlamda, sumak bitkisinin halk sağlığı ve endüstriyel uygulamalar için taşıdığı değerli potansiyel değerlendirilmektedir.

Anahtar Kelimeler: Sumak, biyoaktif bileşikler, biyolojik aktivite, kimyasal bileşim

ABSTRACT

Sumac (*Rhus coriaria L.*) is a plant species rich in bioactive compounds, notable for its traditional and modern applications. Thanks to its constituents, such as polyphenols, flavonoids, tannins, and volatile oils, it exhibits diverse biological activities, including antioxidant, antimicrobial, anti-inflammatory, anticancer, and antidiabetic properties. These attributes position sumac as a significant natural resource in various industries, including food, health, cosmetics, and pharmaceuticals. In the food industry, sumac is used as a natural preservative and colorant, enhancing food safety and extending shelf life due to its antimicrobial effects. In the cosmetics sector, it is incorporated into formulations that support skin health, while pharmacologically, it is believed to assist in the prevention and treatment of various diseases. Furthermore, its potential benefits in agricultural and environmental applications are being explored. This review discusses the chemical composition, biological effects, and health benefits of sumac in detail. Additionally, the industrial applications of the plant across various sectors and the challenges related to sustainable production methods are examined. The study aims to contribute to the scientific understanding of sumac's multifaceted bioactive properties and its application potential. In this context, the valuable potential of sumac for public health and industrial applications is thoroughly evaluated.

Keywords: Sumac, bioactive compounds, biological activity, chemical composition

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Giriş

Sumak (*Rhus coriaria* L.), Anacardiaceae (Menengiçgiller) familyasına mensup, İngilizce'deki karşılığı "sumac" olan, yabani şifalı bir tıbbi ve aromatik bir bitki türüdür (Gharaei vd., 2013; Abu-Reidah vd., 2014; Giovanelli vd., 2017; Morshedloo vd., 2018; Moghadam vd., 2020; Akay vd., 2023; Zannou vd., 2025). Dünya genelinde bu cinse ait 250 tür bulunmaktadır (Rayne ve Mazza, 2007). *Rhus coriaria* L., bu 250 cinsin arasında ekonomik olarak en değerli türdür (Batiha vd., 2022). Sumak ismi, Suriye'deki dilde, kırmızı anlamına gelen "sumaqa" kelimesinden türemiştir (Akay vd., 2023). Ülkemizde; "somak, somalık, tatari, tetri, titre ve tutum" gibi isimlerle de anılmaktadır (Ünder ve Saltan, 2019).

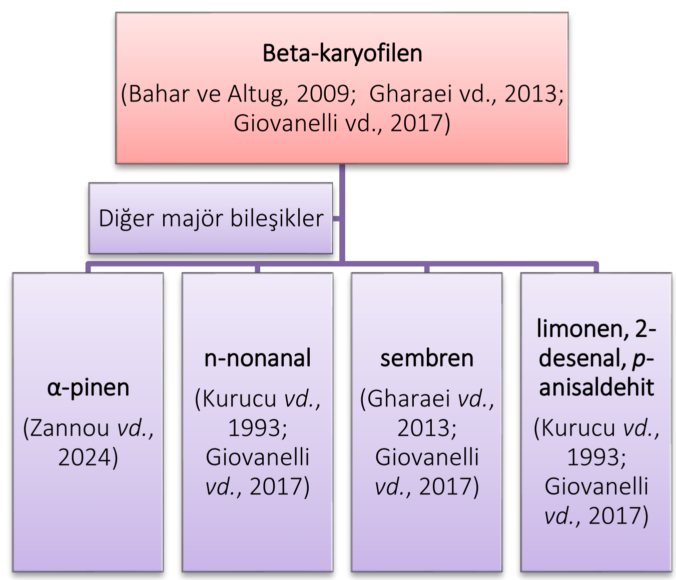
Boyu (1-3) m arasında değişen ve çalı veya küçük ağaç (ağaççık) şeklinde olan sumak bitkisi, ilk olarak yeşilimsi beyaz çiçeklere ve sonradan küre şekilli salkımlar halinde lokalize olan meyvelere sahip olup olgunlaşma ile bu meyveler, kahverenginden kırmızıya dönüşür (Abu-Reidah vd., 2014; Zannou vd., 2025). Her meyvede, bir adet tohum bulunur (Abu-Reidah vd., 2014; Zannou vd., 2025).

Sumak, ılıman ve subtropik iklimleri sever. Dünya genelinde özellikle Afrika, Güneydoğu Anadolu, Akdeniz ve Batı Asya bölgelerinde yayılım göstermektedir (Zannou vd., 2025). Ülkemizde bu bitkiyi, kıyı bölgelerde (özellikle batı ve güney kesimlerde, Marmara ve Karadeniz bölgelerinin kıyı lokasyonlarında vb.) tek veya gruplar halinde yol kenarlarında ve ormanlık bölgelerde görmek mümkündür (Rayne ve Mazza, 2007; Nayebpour ve AsadiGharneh, 2019; Akay vd., 2023; Zannou vd., 2025). Dünya genelinde Akdeniz iklimi görülen bölgelerde yetişmekte ve Lübnan, Suriye, Türkiye, Ürdün ve İran gibi ülkelerde baharat olarak kullanılmaktadır (Alsamri vd., 2021).

Akdeniz havzası ve Orta Doğu'ya özgü olan sumak, antik çağlardan beri terapötik ve besleyici özellikleriyle bilinen, özellikle ekşi limonumsu tadı, sindirimi kolaylaştırıcı ve iştah açıcı özellikleri sayesinde doğu mutfağında yaygın olarak kullanılan bir bitkidir. Sumağın farklı kısımlarından takviye (suplement) kapsül ve uçucu yağ üretimi sağlanmaktadır (Alsamri vd., 2021). Antik dönemlerde, Romalılar ve Yunanlılar, sumak bitkisini limon ve sirke yerine kullanmış ve sindirimi kolaylaştırıcı etkisi ile ateş düşürücü özelliklerinden faydalanmışlardır (Zannou vd., 2025). Bu tip özellikleri, sumağın bileşimindeki biyoaktif bileşiklerden kaynaklanmaktadır.

Sumak Bitkisinin Biyoakif Bileşikleri

Sumak (*Rhus coriaria* L.), bileşiminde fenolik bileşikler, antosiyaninler ve flavonoitler (agastiflavon, amentoflavon, sumaflavon, kuersetin, miresetin, kamferol, delfidin-3-glukozit, siyanidin-3-glukozit ve peonidin-3-glukozit), mineraller, nitrat ve nitritler, organik asitler, proteinler, tanenler, uçucu yağlar ve vitaminler gibi birçok önemli unsuru ve bileşiği içermektedir (Akay vd., 2023; Taşkıran vd., 2023; Zannou vd., 2025). Bu fitokimyasallar, sumak bitkisine biyoaktif özellikler kazandırmaktadır. Biyoaktif bileşikler arasında önemli bir yeri olan uçucu yağ, özellikle bitkinin meyvelerinde bulunur (Bahar ve Altug, 2009; Giovanelli vd., 2017). Bitkiden elde edilen uçucu yağda, önemli majör ve minör bileşikler bulunmakta olup bunlar; lokasyonlara, hasat zamanına, işlemeye ve tarımsal uygulamalara göre değişkenlik gösterirler (Morshedloo vd., 2015; Morshedloo vd., 2018). Uçucu yağındaki majör bileşik, beta-karyofilendir (Bahar ve Altug, 2009; Gharaei vd., 2013; Giovanelli vd., 2017; Johnson vd., 2020). Bunun yanı sıra, farklı kaynaklarda, β-karyofilen ile birlikte, Şekil 1'de gösterilen majör bileşiklerin de bulunduğu ifade edilmiştir (Kurucu vd, 1993; Gharaei vd., 2013; Giovanelli vd., 2017; Zannou vd., 2025).

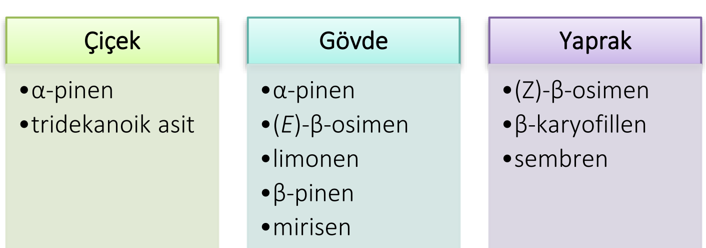


Şekil 1.

Sumağın meyvelerinden elde edilen uçucu yağdaki majör bileşikler (Kurucu vd., 1993; Gharaei vd., 2013; Giovanelli vd., 2017; Zannou vd., 2025)

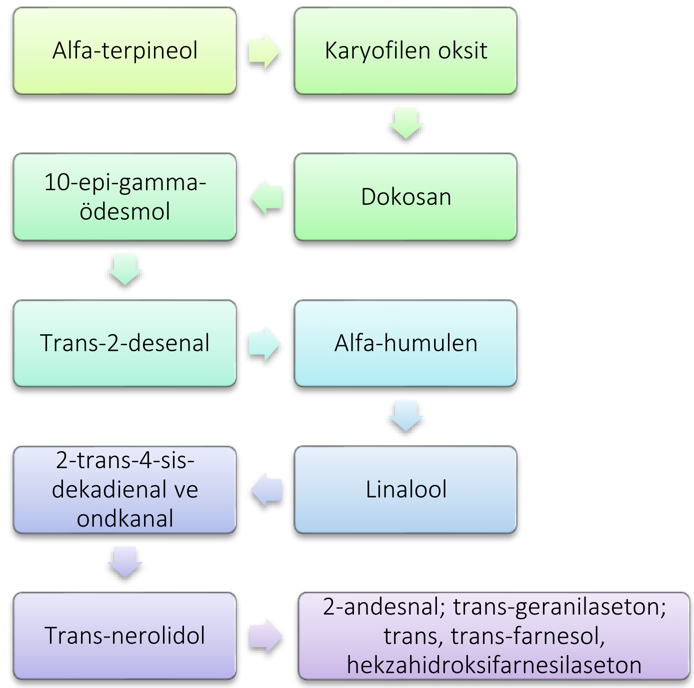
Genel olarak incelendiğinde ise, uçucu yağdaki temel bileşik grupları; monoterpenoitler, diterpenoitler, seskiterpenoitler ve alifatik bileşiklerdir (Moghadam vd., 2020). Başka bir kaynakta; meyveden elde edilen uçucu yağda temel bileşiklerin ve grupların; alifatik aldehitler, farnesil aseton, hekzahidrofarnesil aseton, oksijenli terpenler (karvakrol, karyofilen alkol, α-terpineol vb.), terpen hidrokarbonlar (β-karyofilene ilaveten, α-pinen ve sembren) oldukları bildirilmiştir (Wieczorek vd., 2022). Bir diğer çalışmada, uçucu yağdaki majör bileşiklerin; β-karyofilen (%34,3) ve sembren (%23,8) oldukları tespit edilmiştir (Zhaleh vd., 2018). Bundan başka yapılan bir çalışmada, meyveden elde edilen uçucu yağdaki majör bileşenlerin; *p*-anisaldehit, (Z)-2-heptenal, (E)-2-desenal, β-karyofilen ve sembren oldukları belirtilmiştir (Giovanelli vd., 2017).

Uçucu yağdaki bileşiklerin farklı olmasında, uçucu yağın elde edildiği bitkinin çeşitli kısımları etkili olmaktadır. Bununla ilgili olarak yapılan bir bilimsel çalışmada; bitkinin çiçek, gövde ve yapraklarından elde edilen uçucu yağlardaki majör bileşenlerin, Şekil 2'deki gibi oldukları tespit edilmiştir (Reidel vd., 2017). Bir diğer araştırmada; sumağın meyveleri, karanlık bir ortamda kurutulmuş ve öğütülerek toz haline getirilmiştir. Ardından distilasyonla uçucu yağı elde edilmiş ve majör bileşenlerin başta; beta-karyofilen (%20,2), sembren (%11,1) ve heptenil-akrolein (%5,5) oldukları ve bunları, diğer önemli bileşiklerin takip ettiği tespit edilmiştir (Şekil 3) (Moghadam vd., 2020). Yine aynı çalışmada az miktarda; hekzan, kamfen, 2-heptanon, β-mirisen, β-pinen, β-selinen, 1-okten-3-ol, oktanal, *p*-simen, limonen, sis- ve trans-osimen, oktanol, terpinolen, fençol, dekanal, linalil asetol, trans-3-karen-2-ol, α-terpinil asetal, 2-andesnal, izoamil benzoat, trans-geranilaseton, germakrin, α-ödesmol, α-selinen, laden, globulol, ikosan, heneikosan vb. tespit edilmiştir (Moghadam vd., 2020). Türkiye'de yapılan bir çalışmada; farklı bölgelerden toplanan sumak bitkisinin (ağaç dal ve kabukları, meyve, yaprak) hidrodistilasyon yöntemiyle elde edilen uçucu yağında majör bileşikler olarak (Z)-2-desenal ve sembren tespit edilmiştir (Kurucu vd., 1993).



Şekil 2.

Sumak bitkisinin çiçek, gövde ve yaprak kısımlarından elde edilen uçucu yağdaki majör bileşikler (Reidel vd., 2017)



Şekil 3.

Sumağın meyvelerinden elde edilen uçucu yağdaki diğer önemli bileşikler (Moghadam vd., 2020)

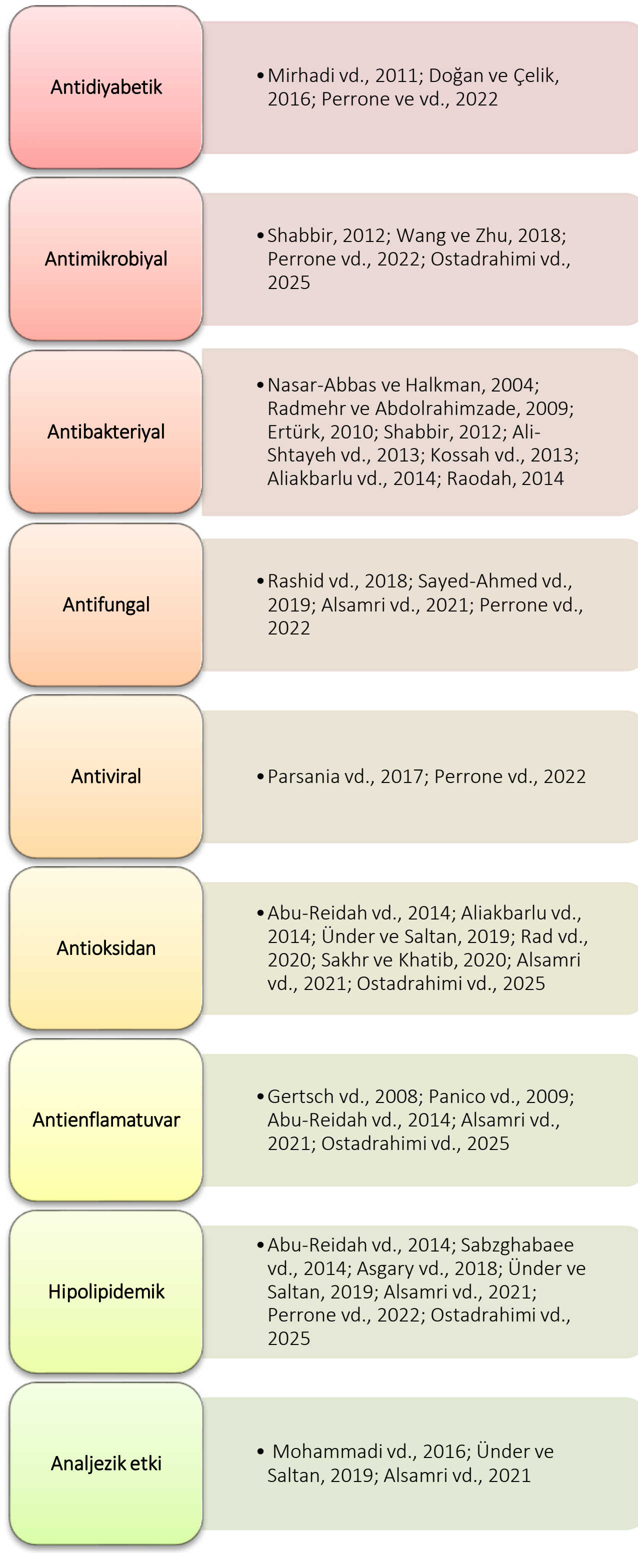
Sumak bitkisinin uçucu yağı ile ilgili çalışmalar, bunlarla sınırlı kalmayıp yapılan bir diğer araştırmada; İran'ın farklı bölgelerinden toplanan meyvelerin hidrodistilasyonla elde edilen uçucu yağında majör bileşikler (GC-MS sonuçlarına göre) olarak; (E)-karyofilen (%50,3), n-nonanal (%23,3), sembren (%21,7), α-pinen (%19,7), (2E,4E)-dekadienal (%16,5) ve nonanoik asit (%15,8) tespit edilmiştir (Morshedloo vd., 2018). Bunlar haricinde az miktarda; kamfen, limonen, mirisen, terpinolen, undekanal, n-dekan, n-dekanal, β-pinen, β-osimen, *p*-simen, ɣ-terpinen, ɣ-muurolen, ɣ-kadinen, α-fellandren, α-terpineol, α-terpinil asetat, α-kopaen vb. bileşikler tespit edilmiştir (Morshedloo vd., 2018). İran'da yapılan bir diğer araştırmada; bitkiden elde edilen uçucu yağdaki majör bileşiklerin, β-karyofilen (%30,7) ve sembren (%21,4) oldukları belirlenmiştir (Gharaei vd., 2013). Bu majör bileşenleri sırasıyla; limonen (%5,3), *p*-simen (%4,8), α-terpinen (%4,5), karvakrol (%3,9), α-humulen (%2,4), α-terpineol (%1,5), α-pinen (%1,4), terpinolen (%1,2) ve %1,1 oranlarında α-kopaen ve β-fellandren izlemiştir. Bunlardan başka, az miktarda; kamfen, β-pinen, mirisen, linalool, linalil-asetat, 2-oktanon, germakrin-D ve 1,8-sineol bileşikleri tespit edilmiştir (Gharaei vd., 2013).

Uçucu yağa ilaveten sumak bitkisi, birçok vitamin bakımından önemli bir bitkisel kaynaktır (Akay vd., 2023). Sumaktaki vitaminler arasında tiyamin (B_1 vitamini), riboflavin (B_2 vitamini), nikotinamit (B_3 vitamini), piridoksin

(B_6 vitamini), biyotin (B_7 vitamini), kobalamin (B_{12} vitamini) ve askorbik asit (C vitamini) bulunmaktadır (Alsamri vd., 2021). Bunun yanı sıra kalsiyum, fosfor, magnezyum ve demir gibi önemli mineralleri içermektedir (Ünder ve Saltan, 2019). Suriye'de yetişmekte olan sumak bitkisinin kurutulmuş meyvelerinde; B_6 vitamini, lösin, malik asit, oleik asit ve potasyum tespit edilmiştir (Kossah vd., 2009). Ayrıca sumak bitkisinin perikarp kısmında tespit edilen malik asit ($C_4H_6O_5$), tartarik asit ($C_4H_6O_6$) ve sitrik asit ($C_6H_8O_7$) gibi organik asitlerle birlikte; içeriğinde bulunan flavonlar (delfinidin, izokersetin, mirsetin, siyanidin), antosiyanidinler (pelargonidin, peonidin, siyanidin vb.) ve fenolik asitler (elajik, p-hidroksibenzoik, protokateşik ve vanilik asitler) gibi fenolik bileşikler, antioksidan etki üzerinde etkilidirler (Baytop, 1999; Kosar vd., 2007; Abu Reidah vd., 2014; (Tang ve Yang, 2018; Ünder ve Saltan, 2019). Sumak bitkisindeki bazı önemli fenolik bileşikler arasında; gallik asit, metil gallat, elajik asit, sirinjik asit, protokateşuik asit, klorojenik asit, siyanidin, delfinidin, izorhamnetin, apigenin ve kuersetin gibi fenolik asitler, antosiyaninler ve flavonoitler yer almaktadır (Batiha vd., 2022).

Sumak Bitkisinin Etkileri ve Kullanım Alanları

Sumak (*Rhus coriaria* L.), içermiş olduğu birçok önemli biyoaktif bileşik sayesinde önemli biyolojik özellikler sergilemekte ve birçok alanda kullanım olanağı bulmaktadır (Rayne ve Mazza, 2007; Abu-Reidah vd., 2014; El Hasasna vd., 2015; Akay vd., 2023; Zannou vd., 2025). Özellikle bileşimindeki baskın fitokimyasallar olan antosiyaninler, fenolik asitler, flavonoitler ve organik asitler, sumak bitkisini hem farmakolojik yönden hem de tüketicilerin bu bitkiyi diyetlerinde tercih etmeleri açısından önemli hale getirmektedir (Zannou vd., 2025). Şekil 4 incelendiğinde, sumağın birçok önemli biyolojik özelliğinin olduğu açıkça görülmektedir.



Şekil 4.

Sumağın önemli biyolojik özellikleri

Sumağın sahip olduğu en önemli özelliklerinden birisi, antimikrobiyal etkili olmasıdır. Yapılan bir çalışmada; bitkinin uçucu yağının antimikrobiyal etkili olduğu ve

Bacillus subtilis, *Escherichia coli*, *Pseudomonas aeruginosa* ve *Staphylococcus aureus*'a karşı etki gösterdiği ve bu sayede, bazı bakteriyal enfeksiyonlarda antibiyotik olarak kullanılabileceği vurgulanmıştır (Zhaleh vd., 2018). Bir diğer çalışmada; sumaktan elde edilen uçucu yağın, başta *Streptococcus mutans* olmak üzere *Lactobacillus rhamnosus* ve *Actinomyces viscosus*'a karşı inhibitör etki gösterdiği belirlenmiştir (Moghadam vd., 2020). Antimikrobiyal aktivitenin yanı sıra sumağın antioksidan etkisi de bulunmaktadır (Zannou vd., 2025). Meyve ve tohumlardaki antioksidan etkiler, A ve C vitaminleri sayesinde görülür (Abu-Reidah vd., 2014). Antioksidan etki üzerinde esasen etkili olan diğer önemli bileşikler ise, sumakta bulunan fenolik bileşiklerdir (özellikle gallik asit ve türevleri) (Kosar vd., 2007; Chakraborty vd., 2009; Ünder ve Saltan, 2019; Rad vd., 2020; Sakhr ve Khatib, 2020; Akay vd., 2023). Gallik asit gibi, antosiyaninler ve hidrolize olabilen tanenler (Tablo1), lipit peroksidasyonunu engelleyen diğer önemli fenolik yapılardandır (Kosar vd., 2007).

Tablo 1.

Sumak meyvesindeki temel bileşikler (Batiha vd, 2022)

Bileşik grupları	Alt-bileşik grupları	Kaynaklar
Yapraklar, meyveler ve tohumlardaki antosiyaninler	Siyanidin, peonidin, pelargonidin, petunidin, kumaratlar, delfinidin, mirtillin, krisantemin	Abu-Reidah vd., 2015
Yapraklar, meyveler ve tohumlardaki hidrolize olabilen tanenler	Gallik asit, metal gallat, digallik asit, tri-gallik asit, ellajik asit, galloilheksoz, o-galloilmorbergenin, o-galloil arbutin	Abu-Reidah vd., 2015

Sumağın ayrıca dezenfektan, diüretik ve iştah açıcı etkileri olduğu bilinmektedir (Abu-Reidah vd., 2014; Elagbar vd., 2020). Bu etkilerinin yanı sıra sergilemiş olduğu antienflamatuvar etkinin, uçucu yağda bulunan β-karyofilen sayesinde gerçekleştiği ifade edilmiştir (Gertsch vd., 2008). Buna ilaveten, bilimsel kaynaklarda sumak bitkisinin birçok önemli biyolojik etkisinin olduğu bildirilmekte olup bunlar arasında; antiviral, antimikrobiyal, antienflamatuvar, antioksidan ve antidiyabetik etkiler; serbest oksijen radikali temizleyici etki; antihemolitik (kırmızı kan hücrelerinin yıkımını azaltan veya önleyici) etki; karaciğer hasarına karşı koruyucu (hepatoprotektif) etki ve antifibrojenik (akciğerde yara dokusunun artmasını yavaşlatıcı) etki bulunmaktadır (Hamdan vd., 2017; Alpsoy vd., 2019; Hüseyinova vd., 2020; Ostadrahimi vd., 2025).

Sumak, yüzyıllardır baharat olarak ve geleneksel halk tıbbında (halk arasında tıbbi olarak) kullanılan bir bitkidir (Ali-Shtayeh vd., 2008; Ünder ve Saltan, 2019). Bitki, geleneksel halk hekimliğinde genel olarak akonürez (istem dışı idrara çıkma), baş ağrısı, çiçek hastalığı, damar sertleşmesi, dermatit, diş ve dişeti rahatsızlıkları, diürez (idrarın fazlalaşması), diyabet, dizanteri, diyare, felç, hayvan ısırmaları, hematemez (kan kusma), karaciğer hastalıkları, kızamık, hipertansiyon, kanser, mide ağrısı, oftalmi (göz iltihabı) gibi birçok hastalığın tedavisinde kullanılmaktadır (Abu-Reidah vd., 2015; Elagbar vd., 2020; Zannou vd., 2025). Bundan başka; İran ve Orta Doğu'da dizanteri, ishal, mide bulantısı, hemoroit ve gut hastalığının tedavisinde; yaraların iyileştirilmesinde ve kan şekeri, kolesterol ve ürik asit seviyelerinin indirilmesi amacıyla yüzyıllardır kullanılmaktadır (Rayne ve Mazza, 2007; Ahmad vd., 2013; Zhaleh vd., 2018). Türkiye'de sumağın meyvelerinden ve yapraklarından halk arasında geleneksel olarak ağızdaki yaraların iyileştirilmesinde ve şeker hastalığının tedavisinde faydalanılmaktadır (Kurucu vd., 1993). Ağızdaki yaraların ve midede oluşan krampların iyileştirilmesinde, sumağın meyveleri sakız gibi çiğnenebilmektedir (Tuzlacı, 2006; 2011). Bundan başka, yağ formunda işlenip tüketilen sumak, halk tıbbında sindirim ve idrar yolu rahatsızlıkları ile göğüs ağrısı gibi bazı hastalıkların tedavisinde kullanılmaktadır (Abu-Reidah vd., 2015). Sumak, terlemeyi teşvik eder, ateşin düşürülmesinde yardımcı olur ve bağırsak tahrişine karşı koruma sağlar. Demlendiğinde, cilt enfeksiyonlarını da hafifletir. Tıbbi bir bitki olarak kullanılan sumak, ayrıca antiseptik özelliği sayesinde boğaz ağrısını gidermek amacıyla kullanılmaktadır (Sakhr ve El Khatib, 2020). Sumak, kolesterol düşürücü ve antienflamatuvar olarak da kullanılmaktadır (Khalil vd., 2021). Kaynatılarak hazırlanan sumak, günümüzde halâ Orta Doğu mutfağında yaygın olarak kullanılmakta ve mide rahatsızlıklarını hafifletmek amacıyla tüketilmektedir (Zannou vd., 2025). Amerika Birleşik Devletleri'nin ılıman bölgelerinde bulunan beyaz sumak, Yerli Amerikalılar tarafından hemoroit, iltihap ve ağız yaralarının tedavisinde kullanılmıştır. Aynı zamanda romatizmayı hafifletmek için iyi bir tedavi yöntemidir (Zannou vd., 2025). Sumak, ayrıca kan şekeri seviyelerini düşüren ve diyabet hastalarında glikoz toleransını iyileştiren güçlü hipoglisemik özelliklere sahiptir (Rahideh vd., 2014). Yapraklarının vazodilatör özellikleri, sumak bitkisini kardiyovasküler sistem için koruyucu bir ajan haline getirmektedir. Ayrıca, DNA koruması için antioksidan özelliklere sahiptir (Zannou vd., 2025). Buna ek olarak, başka bir araştırmada; sumak ekstresinin, COVID-19 tedavisindeki potansiyeli rapor edilmektedir (Korkmaz, 2021).

Sumak bitkisinin, Orta Doğu ve Akdeniz ülkelerinin birçoğunda geleneksel olarak tıbbi amaçlarla kullanıldığı bilinmektedir (Reidel vd., 2017). Sumağın meyveleri, saç bakımında (kepek oluşumunun engellenmesinde, saç rengi, saç temizliği vb.) kullanılmaktadır (Gupta vd., 2010). Saç bakımından başka ateşin düşürülmesinde, baş ağrısında, derideki yaralanmalarda (Nozza vd., 2020), derideki yanıkların tedavisinde ve kilo vermede kullanılmaktadır (Jamous vd., 2018). İbn-i Sina, kitabında (El-Kanun fi't-Tıb) bitkinin geleneksel halk tıbbında felç kronik semptom (stroke chronic symptoms) tedavisinde kullanıldığını tarif etmiştir (Zargaran vd., 2013). Bunlara ilaveten, içermiş olduğu tekli doymamış yağ asitleri, insan sağlığı üzerinde birçok olumlu etki (kalp hastalıklarının oluşumunu azaltma, kandaki kolesterolü ve trigliserit seviyelerini düşürücü, iltihaplanmayı azaltıcı vb.) göstermektedir. Bundan başka; sahip olduğu biyolojik özellikler (antiapoptotik, antienflamatuvar, antifibrinojenik, antioksidan, hipoglisemik, lökopenik, sitotoksik vb.), sumağın bir fonksiyonel gıda olarak değerlendirilmesine olanak sağlamaktadır (Karaduman, 2022).

Hippokrates'e (MÖ 400) atfedilen 'Bırak yiyeceklerin ilacın olsun ve ilacın da yiyeceklerin olsun' ifadesi, sağlıklı beslenmenin sağlık üzerindeki faydalarının erken dönemde tanındığını gösterir. Fonksiyonel gıda kavramı, temel besin rollerinin ötesinde hastalık önleyici ve/veya tedavi edici özelliklere sahip işlenmiş gıdaları tanımlamak amacıyla 1980'lerin başlarında Japonya'da ortaya çıkmıştır (Olaiya vd., 2015; Serafini ve Peluso, 2016; Khalil vd., 2021). Bu kavram, beslenme ve farmakoloji arasındaki tamamlayıcılığı vurgulamak amacıyla Stephen DeFelice tarafından türetilen nutrasötik terimi ile sık sık örtüşmektedir (Olaiya vd., 2015). Sumak meyvesi, proteinler, uçucu yağlar, yağ asitleri, lif, mineraller, tanenler, fenolik asitler ve antosiyaninler gibi beslenme ve farmakoloji açısından önemli bileşenlerin geniş bir oranını içermesi nedeniyle fonksiyonel bir gıda olarak kabul edilmiştir (Khoshkharam vd., 2022). Sumak bitkisi (*Rhus coriaria* L.), doymamış yağ asitleri, vitaminler ve mineraller gibi önemli besin maddelerinin zengin ve değerli bir diyet kaynağı olarak değerlendirilir (Tablo 2) (Batiha vd., 2022).

Tablo 2.

Sumak meyvesindeki bazı temel besin öğleri (Batiha vd., 2022)

Besin maddeleri	Birim	Miktar
Oleik asit	%	37,70
Linoleik asit	%	27,40
Palmitik asit	%	21,10
Stearik asit	%	4,70
Diğer yağ asitleri	%	9,10
B_6 vitamini	ppm	69,83
C vitamin	ppm	38,91
B_1 vitamini	ppm	30,65
B_2 vitamini	ppm	24,68
Nikotinamit	ppm	17,95
Potasyum	ppm	7963,35
Kalsiyum	ppm	3661,57
Fosfor	ppm	1238,74
Magnezyum	ppm	855,95
Demir	ppm	144,53

Sumak bitkisinin, baharat olarak gıdalara çeşni ve lezzet vermek amacıyla kullanımı yaygındır (Rayne ve Mazza, 2007; Abu-Reidah vd., 2014; Moghadam vd., 2020). Özellikle uçucu bileşikleri, sumağa eşsiz aroma kazandırmakta ve tüketiciler tarafından kabul edilebilirliğini ve gıda endüstrisindeki kullanımını artırmaktadır (Zannou vd., 2025). Oranları değişmekle birlikte uçucu yağın bileşiminde bulunan beta-karyofilen, sumağa karakteristik baharat lezzetini ve aromasını kazandırır (Morshedloo vd., 2018). Sumak meyveleri, baharat olarak kullanılmak üzere ağaçta kızarıp olgunlaştıktan sonra kurutulup öğütülürler (Kossah vd., 2009; Zannou vd., 2025). Baharat şeklinde yaygın olarak kullanıldığı bölgeler arasında, Akdeniz ve Orta Doğu ülkeleri yer almaktadır (Rayne ve Mazza, 2007; Khoshkharam vd., 2022). Türkiye ve İran'da kanatlı hayvan etlerinden yapılan yemeklerde ve sebze yemeklerinde çeşni olarak ve lezzet katmak amacıyla kullanılmaktadır (Ravindran vd., 2012). Sumak ayrıca Akdeniz bölgelerinde et ve balık yemeklerinde baharat olarak yaygın şeklinde kullanılmaktadır (Alsamri vd., 2021). Bunun yanı sıra, Arap ülkelerinde kekik, susam tohumu ve tuz ile karıştırılarak (yerel ismi dukkah veya za'atar denilen) yemeklerde tüketilmektedir (Farag vd., 2018). Dünyada, genellikle et yemeklerine, sebzelere ve pirince baharat olarak ilave edilir (Zannou vd., 2025). Türkiye'de (Güvenç vd., 2017) özellikle

Güneydoğu Anadolu Bölgesi'nde kuru dolmalarda, kebap çeşitlerinde, kebapların ve et yemeklerinin yanında tüketilen yeşillik ve salata çeşitlerine ilave edilerek tüketilmektedir. Katıldığı yemeklere veya gıdalara ekşi limon tadı katar ve bu özelliğinden ülkemizde de baharat olarak faydalanılır (Şekil 5). Ekşilik, sumağın bünyesindeki organik asitlerden (malik, sitrik ve tartarik asitler) kaynaklanır (Fereidoonfar vd., 2019; Karadaş vd., 2020). Bu asitler, perikarp bölgesinde lokalize olmuş vaziyettedirler (Baytop, 1999; Kosar vd., 2007; Abu Reidah vd., 2014). Sumak meyvesinin baharat olarak kullanımının dışında meyvesinden çay yapıldığı bilinmektedir (Akay vd., 2023). Ayrıca, sumak tek başına veya diğer baharatlarla birlikte içeceklerde, soslarda, iştah açıcı ürünlerde ve doğal asitlik düzenleyici olarak gıdalarda kullanımı bulunmaktadır (Abu-Reidah vd., 2014).

Şekil 5.

Baharat olarak kullanılmak üzere kurutulmuş ve öğütülmüş sumağın kullanıldığı bazı gıdalar

Sumağın, bileşimindeki besin unsurları ve bileşikler sayesinde antioksidan özellik göstermesinin (Karaduman, 2022; Ostadrahimi vd., 2025), zeytinyağın raf ömrüne olumlu yönde etki edebileceğine dair bulgular mevcuttur (Doğan ve Akgül, 2005). Bunun yanı sıra, antioksidan özelliği sayesinde sumak meyveleri, ayçiçek yağını stabilize etmek için kullanılmaktadır (Rayne ve Mazza, 2007). Antioksidan özelliğinden yararlanarak yağ oranı yüksek, bozulmaya karşı hassas diğer ürünler üzerinde de çalışmalar yoğunlaştırılabilir. Bunun yanı sıra, baharat olarak tüketilmesi, tüketicilerin antioksidan özelliğinden de faydalanabileceğini gözler önüne sermektedir. Ayrıca, bir çalışmada; sumak bitkisinin lezzetliliği ve yüksek antioksidan kapasitesi göz önüne alındığında, sumak biyolojik aktif bileşiklerinin uygulanması, gıda endüstrisi için bitkisel kökenli pigmentler ve fitobileşenleri şekersiz ürünler içerisinde sunmada etkili bir çözüm olabileceği ve bu tür ürünlerin, farklı önleyici ve terapötik amaçlarla kullanılabilecek fonksiyonel gıdalar olarak değerlendirilebileceği vurgulanmıştır (Ostadrahimi vd., 2025).

Sumak; gıdalarda baharat olarak kullanımının yanı sıra gıda takviyesi, gıda boyası, doğal gıda koruyucu maddesi ve hayvan yem katkı maddesi olarak değerlendirilmektedir (Sakhr ve El Khatib, 2020; Pakseresht vd., 2023; Ostadrahimi vd., 2025). Gıda alanındaki kullanımları dışında birçok farklı kategoride değerlendirilmesi, sumağın ticari değerini artırmaktadır. Yapılan bir çalışmada, antibakteriyel etki gösterdiği için sumaktan elde edilen uçucu yağın ağız yıkama sularında ve oral enfeksiyon hastalıklarında kullanılabileceği belirtilmiştir (Moghadam vd., 2020). Diş bakımında sorun teşkil eden *Actinomyces*, *Lactobacilli* ve *Streptecocci* (Yu vd., 2017) gibi mikroorganizmalara karşı etkili olduğu için bitkinin uçucu yağının diş bakımında da kullanılabileceği vurgulanmıştır (Moghadam vd., 2020). Ayrıca antosiyaninler gibi doğal pigmentleri içermesi, gıda endüstrisinde doğal boyar madde olarak kullanımını sağlamakta; tanen içeren kabuk, sap ve yapraklar boyama amacıyla kumaşlarda ve dericilikte (özellikle tabaklamada) kullanılmaktadır (Göktürk vd., 2006; Zannou vd., 2022; 2023). Boyar özelliği sayesinde mürekkep yapımında ve boya üretiminde ve bunun yanında, veterinerlik alanında, sumak meyvelerinin ekstreleri kullanılmaktadır (Kurt vd., 2014). Geçmişte sumağın kök, dal ve gövdesinin doğal boyalarda renkleri sabitleştirici olarak kullanıldığı ifade edilmiştir (Abu-Reidah vd., 2014).

Sumak ağacından zirai faaliyetlerde de faydalanılmaktadır. Özellikle verimsiz alanların (maden alanları, erozyon vb. doğal afete uğramış bölgeler vb.) ağaçlandırılmasında önemli bir bitki türü konumundadır (Göktürk vd., 2006). Ağaçlandırmada kullanılabilmesinin en önemli özelliği; kuru, taşlık, çakıllı ve 1900 metre yükseltiye kadar olan alanlarda yetişebilme yeteneğidir (Baytop, 1999).

Sumak, baharat olarak kullanılmak üzere öğütüldükten sonra uygun şekilde muhafaza edilmelidir. Her ne kadar bünyesinde antioksidan karakterli bileşikleri ve unsurları (fenolik bileşikler, gallik asit vb.) barındırdığı için bozulmalara karşı dayanıklılık gösterse de (Kossah vd., 2009; Dalar vd., 2018; Karadaş vd., 2020; Karaduman, 2022; Akay vd., 2023), sumağın, baharat haline dönüştürüldükten sonra diğer baharatlarda olduğu gibi uygun şekilde muhafaza edilmesi sağlanmalıdır. Özellikle, bileşimindeki uçucu ve aromatik bileşiklerin tahrip olmayacak şekilde muhafaza edilmesi gerekmektedir. Bu amaçla; kapaklı cam kaplarda, serin, kuru ve doğrudan güneş ışığı almayan bir yerde bekletilmesine özen gösterilmelidir.

Sonuç ve Öneriler

Sumak (*Rhus coriaria* L.), Menengiçgiller (Anacardiaceae) familyasına mensup, özellikle Akdeniz ve Doğu Asya bölgelerinde yetişen, yurdumuzda çoğunlukla kıyı bölgelerde (Marmara, Karadeniz vb.) bulunan, yaygın şekilde meyveleri kızarıp olgunlaştıktan sonra işlenerek baharat olarak kullanılan önemli bir bitki türüdür. Baharat olarak kullanımında, kendine has hoş aroması ve ekşi limon tadı etkili olmaktadır. Ekşi tadı, bileşimindeki organik asitler olan malik, tartarik ve sitrik asitlerden kaynaklanmaktadır. Organik asitlere ilaveten bünyesinde bulunan uçucu yağ, flavonoitler, antosiyaninler, fenolik asitler (özellikle gallik asit ve türevleri) vitaminler ve mineraller, sumak bitkisine biyoaktivite ve tıbbi yönden değer katmaktadır. Bu sayede sumak, tıbbi ve aromatik bitki olarak değerlendirilmektedir. Tıbbi ve aromatik yönden özellikle *Rhus coriaria* L., ekonomik değeri yüksek kıymetli bir türdür.

Rhus coriaria L., baharat olarak ülkemiz de dahil özellikle doğu (İran, Suriye vb.) mutfağında birçok yemekte ve üründe (et yemekleri, tavuk yemekleri, sebze yemekleri, salatalar vb.) yaygın şekilde kullanılmaktadır. Bunun yanı sıra bileşimindeki biyoaktif bileşikler sayesinde önemli biyolojik özellikler (antimikrobiyal, antioksidan, antienflamatuvar, analjezik, hepatoprotektif, antidiyabetik, antihemolitik, kardiyovasküler vb.) sergiler ve özellikle halk hekimliğinde (akonürez, baş ağrısı, dermatit, diş ve dişeti rahatsızlıkları, diyabet, felç, hipertansiyon, ishal, karaciğer ve kalp hastalıkları, mide ağrısı vb.) değerlendirilir. Bunların yanı sıra birçok endüstri (deri işleme, boya, mürekkep, veterinerlik vb.) dalında kullanım olanağı bulmaktadır. Özellikle bünyesindeki antosiyaninler sayesinde doğal boyar madde olarak gıda endüstrisinde kullanılmaktadır. Bundan başka bileşimindeki gallik asit ve türevleri, antosiyaninler ve hidrolize olabilen tanenler gibi fenolik bileşikler sayesinde, antioksidan aktivite sergilemekte, lipit peroksidasyonunu engellemekte ve bu özelliği sayesinde yenilebilir bitkisel yağların (ayçiçek yağı vb.) korunmasında kullanım olanağı bulmaktadır. Bundan başka, patojenler üzerinde antimikrobiyal özellikler sergilemesi, gıdaların muhafazası açısından sumak bitkisinin kullanılabilirlik potansiyelini artırmaktadır. Tüm bu parametreler dikkate alındığında; özellikle gıda alanında sumak bitkisi ile ilgili laboratuvar ve klinik çalışmaları yaygınlaştırılarak doğal yolla muhafaza yöntemleri geliştirilebilir ve/veya yaygınlaştırılabilir. Buna ilaveten, sumak bitkisinin zorlu çevre (yüksek rakım) ve toprak şartlarında (çakıllı, taşlı vb.) yetişmesi, bu bitkinin çorak alanların ağaçlandırılmasında kullanılabilmesi açısından çok önemli bir kriterdir. Buradan yola çıkılarak, boş çorak arazilerde sumak yetiştiriciliği yapılabilir. Bu sayede hem bu tip alanların yeşillendirilmesi hem de buradan elde edilecek ürünlerle ülke ekonomisine katkı sağlanmış olur. Ayrıca, sumak üretiminin teşvik edilmesi ile biyoaktif bileşiklerinin tıbbi ve farmakolojik alanlarda daha fazla değerlendirilebileceği hammadde temini arttırılabilir.

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Abu-Reidah, I. M., Jamous, R. M., & Ali-Shtayeh, M. S. (2014). Phytochemistry, Pharmacological Properties and Industrial Applications of *Rhus coriaria* L. (Sumac). *Jordan Journal of Biological Sciences*, *7*(4), 233-244.

Abu-Reidah, I. M., Ali-Shtayeh, M. S., Jamous, R. M., Arráez-Román, D., & Segura-Carretero, A. (2015). HPLC-DAD-ESI-MS/MS screening of bioactive components from *Rhus coriaria* L. (Sumac) fruits. *Food Chemistry.*, *166*, 179-191.

Ahmad, H., Ahmad, F., Hasan, I., & Ahmad, S. (2013). Unani description of Sumaq (*Rhus coriaria* Linn.) and its scientific report. *Global Journal of Medical Research*, *13*, 74-78.

Akay, E., Yılmaz, İ., & Eyioğlu, U. (2023). Sumak (*Rhus coriaria* L.) Bitkisinin Fitoterapide Kullanımı ve Gastronomik Değeri. *Journal of Academic Tourism Studies*, *4*(1), 56-65.

Aliakbarlu, J., Mohammadi, S., & Khalili, S. (2014). A Study on Antioxidant Potency and Antibacterial Activity of Water Extracts of Some Spices Widely Consumed in Iranian Diet. *Journal of Food Biochemistry*, *38*, 159-166.

Ali-Shtayeh, M. S., Jamous, R. M., Al-Shafie, J. H., Elgharabah, W. A., Kherfan, F. A., Qarariah, K. H., Khdair, I. S., Soos, I. M., Musleh, A. A., Isa, B. A., Herzallah, H. M., Khlaif, R. B., Aiash, S. M., Swaiti, Gh. M., Abuzahra, M. A., Haj-Ali, M. M., Saifi, N. A., Azem, H. K., & Nasrallah, H. A. (2008). Traditional knowledge of wild edible plants used in Palestine (Northern West Bank): a comparative study. *J Ethnobiol Ethnomed*, *4*, 1-122.

Alpsoy, L., Yalçın, F. N., Ercan, P., Karagöz, A., & Cengiz, M. (2019). Hepatoprotective Effects of Sumac (*Rhus coriaria* L.) Extract on Liver Damage Induced by Carbon Tetrachloride in Rats. *Biomedicine & Pharmacotherapy*, *109*, 101-107.

Alsamri, H., Athamneh, K., Pintus, G., Eid, A. H., & Iratni, R. (2021). Pharmacological and antioxidant activities of *Rhus coriaria* L. (Sumac). *Antioxidants*, *10*(1), 1-28.

Asgary, S., Salehizadeh, L., Keshvari, M., Taheri, M., Spence, N. D., Farvid, M. S., RafieianKopaei, M., & Sarrafzadegan, N. (2018) Potential cardioprotective effects of sumac capsule in patients with hyperlipidemia: A triple-blind randomized, placebo-controlled crossover trial. *Journal of the American College of Nutrition*, *37*, 286-292.

Bahar, B., & Altug, T. (2009). Flavour characterization of sumach (*Rhus coriaria* L.) by means of GC/MS and sensory flavour profile analysis techniques. *International Journal of Food Properties.*, *12*, 379-387.

Batiha, G. E.-S., Ogunyemi, O. M., Shaheen, H. M., Kutu, F. R., Olaiya, C. O., Sabatier, J.-M., & De Waard, M. (2022). *Rhus coriaria* L. (Sumac), a Versatile and Resourceful Food Spice with Cornucopia of Polyphenols. *Molecules*, *27*, 1-21.

Baytop, T. (1999). Türkiye'de Bitkiler ile Tedavi Geçmişte ve Bugün, ilaveli 2. Baskı. Nobel Kitabevi, İstanbul.

Chakraborty, A., Ferk, F., Simić, T., Brantner, A., Dušinská, M., Kundi, M., Hoelzl, C., Nersesyan, A., & Knasmüller, S. (2009). DNA-protective effects of sumac (*Rhus coriaria* L.), a common spice: Results of human and animal studies. *Mutation Research, Fundamental and Molecular Mechanisms of Mutagenesis*, *661*, 10-17.

Dalar, A., Dogan, A., Bengu, A. S., Mukemre, M., & Celik, I. (2018). Screening in Vivo Antioxidant and Haematological Properties of Sumac and Acorn Bioactive Rich Extracts. *Industrial Crops and Products.*, *124*, 20–27.

Dogan, M., & Akgul, A. (2005). Characteristics and fatty acid compositions of *Rhus coriaria* cultivars from Southeast Turkey. *Chemistry of Natural Compounds*, *41*(6), 724-725.

Doğan, A., & Çelik, İ. (2016). Healing effects of sumac (*Rhus coriaria*) in streptozotocin-induced diabetic rats. *Pharmaceutical Biology.*, *54*, 2092-2102.

Elagbar, Z. A., Shakya, A. K., Barhoumi, L. M., & Al-Jaber, H. I. (2020). Phytochemical Diversity and Pharmacological Properties of *Rhus coriaria*. *Chemistry & Biodiversity*, *17*(4), e1900561.

El Hasasna, H., Athamneh, K., Al Samri, H., Karuvantevida, N., Al Dhaheri, Y., Hisaindee, S., Ramadan, G., Al Tamimi, N., AbuQamar, S., & Eid, A. (2015). *Rhus coriaria* induces senescence and autophagic cell death in breast cancer cells through a mechanism involving p38 and ERK1/2 activation. *Scientific Reports*, *5*, 13013.

Ertürk, Ö. (2010). Antibacterial and antifungal effects of alcoholic extracts of 41 medicinal plants growing in Turkey. *Czech Journal of Food Sciences.*, *28*, 53-60.

Farag, M. A., Fayek, N. M., & Reidah, I. A. (2018). Volatile profiling in *Rhus coriaria* fruit (sumac) from three different geographical origins and upon roasting as analyzed via solid-phase microextraction. *PeerJ*, *6*, 1-16.

Fereidoonfar, H., Salehi-Arjmand, H., Khadivi, A., Akramian, M., & Safdari, L. (2019). Chemical Variation and Antioxidant Capacity of Sumac (*Rhus coriaria* L.). *Industrial Crops and Products*, *139*, 111518.

Gertsch, J., Leonti, M., Raduner, S., Racz, I., Chen, J- Z., Xie, X- Q., Altmann, K. H., Karsak, M., & Zimmer, A. (2008). Betacaryophyllene is a dietary cannabinoid. *Proceedings National Academy of Sciences.*, *105*, 9099-9104.

Gharaei, A., Khajeh, M., Ghaffari, M., & Choopani, A. (2013). Iranian *Rhus coriaria* (sumac) essential oils extraction. *Journal of Essential Oil Bearing Plants.*, *16*, 270-273.

Giovanelli, S., Giusti, G., Cioni, P.L., Minissale, P., Ciccarelli, D., & Pistelli, L. (2017). Aroma profile and essential oil composition of *Rhus coriaria* fruits from four Sicilian sites of collection. *Industrial Crops and Products*, *97*, 166-174.

Göktürk, A., Ölmez, Z., & Temel, F. (2006). Some Native Plants for Erosion Control Efforts in Coruh River Valley, Artvin, Turkey. *Pakistan Journal of Biological Sciences*, *9*(4).

Gupta, A., Malviya, R., Singh, T. P., & Sharma, P. K. (2010). Indian medicinal plants used in hair care cosmetics: a short review. *Pharmacognosy Journal*, *2*, 361-364.

Güvenç, G., Özcan, A., Bükücü, Ş. B., & Sütyemez, M. (2017). Bazı Derici Sumak (*Rhus coriaria* L.) Genotiplerinin Fenolojik Özelliklerinin Belirlenmesi.

Türk Tarım ve Doğa Bilimleri Dergisi, *4*(4), 477–483.

Hamdan, D., Ashhab, Y., Shihadeh, W., & Zidan, J. (2017). In-Vitro Investigation of the Anti-Hemolytic and Anti-Cytotoxic Effect of Rhus Coriaria L. Extracts. *BMC Complementary and Alternative Medicine*, *17*(1), 167.

Hüseyinova, G., & Mammadova, G. (2020). In Vitro Antiviral Activity of *Rhus coriaria* L. Extracts Against Herpes Simplex Virus Type 1. *Natural Product Research*, *34*(12), 1665-1668.

Jamous, R. M., Abu-Zaitoun, S. Y., Akkawi, R. J., & Ali-Shtayeh, M. S. (2018). Antiobesity and Antioxidant Potentials of Selected Palestinian Medicinal Plants. *Evidence-Based Complementary and Alternative Medicine.*, 8426752.

Johnson, S. A., Rodriguez, D., & Allred, K. (2020). A Systematic Review of Essential Oils and the Endocannabinoid System: A Connection Worthy of Further Exploration. *Hindawi Evidence-Based Complementary and Alternative Medicine*, *2020*, 1-13.

Karadaş, Ö., Yılmaz, İ., & Geçgel, Ü. (2020). Sumak (*Rhus coriaria* L.) Meyvesinin Fizikokimyasal Özellikleri. *Trakya University Journal of Engineering Sciences.*, *21*(2), 87-94.

Karaduman, N. (2022). *Sumak (Rhus coriaria) Bitkisinin Beslenme ve Fitoterapide Kullanımı Üzerine Araştırmalar*. [Yüksek Lisans Tezi]. Bezmialem Vakıf Üniversitesi Sağlık Bilimleri Enstitüsü Farmakognozi ve Doğal Ürünler Kimyası Anabilim Dalı Farmakognozi ve Doğal Ürünler Kimyası Tezli Yüksek Lisans Programı.

Khalil, M., Hayek, S., Khalil, N., Serale, N., Vergani, L., Calasso, M., De Angelis, M., & Portincasa, P. (2021). Role of Sumac (*Rhus coriaria* L.) in the management of metabolic syndrome and related disorders: focus on NAFLD-atherosclerosis interplay. *Journal of Functional Foods.*, *87*, 104811.

Khoshkharam, M., Shahrajabian, M. H., Singh, R. B., Sun, W., Magadlela, A., Khatibi, M., & Cheng, Q. (2022). *Chapter 17- Sumac: A Functional Food and Herbal Remedy in Traditional Herbal Medicine in the Asia, in Functional Foods and Nutraceuticals in Metabolic and Non-Communicable Diseases*; Singh, R.B.,Watanabe, S., Isaza, A.A., Eds.; Academic Press: Cambridge, MA, USA, pp. 261–266.

Korkmaz, H. (2021). Could sumac be effective on COVID-19 treatment? *J Med Food*, *24*(6), 563–568.

Kosar, M., Bozan, B., Temelli, F., & Baser, K. H. C. (2007). Antioxidant activity and phenolic composition of sumac (*Rhus coriaria* L.) extracts. *Food Chemistry*, *103*, 952-959.

Kossah, R., Nsabimana, C., Zhao, J., Chen, H., Tian, F., Zhang, H., & Chen, W. (2009). Comparative study on the chemical composition of Syrian sumac (*Rhus coriaria* L.) and Chinese sumac (*Rhus typhina* L.) fruits. *Pakistan Journal of Nutrition*, *8*, 1570–1574.

Kurt, R., Karayılmazlar, S., & Çabuk, Y. (2014). Sepicilikte Kullanılan Odun Dışı Orman Ürünlerinin Dış Ticaretinin Değerlendirilmesi, Akdeniz ormanlarının geleceği: Sürdürülebilir toplum ve çevre. *II. Ulusal Akdeniz Orman ve Çevre Sempozyumu*, 650-656, Isparta.

Kurucu, S., Koyuncu, M., Güvenç, A., Baser, K., & Özer, T. (1993). The essential oils of *Rhus coriaria* L. (Sumac). *Journal of Essential Oil Research.*, *5*, 481-486.

Mirhadi, K., Daryoush, B., & Saeid, S. (2011). Orally administration effect of Sumac on blood sugar in rat. *Advances in Environmental Biology.*, *5*, 2077-2079.

Moghadam, P., Dadelahi, S., Hajizadeh, Y. S., Matin, M. G., Amini, M., & Hajazimian, S. (2020). Chemical Composition and Antibacterial Activities of Sumac Fruit (*Rhus coriaria*) Essential Oil on Dental Caries Pathogens. *The Open Microbiology Journal*, *14*, 143.

Mohammadi, S., Zarei, M., Zarei, M. M., & Salehi, İ. (2016). Effect of hydroalcoholic leaves extract of *Rhus coriaria* on pain in male rats. *Anesthesia and Pain Medicine.*, *6*, 1-5.

Morshedloo, M. R., Ebadi, A., Maggi, F., Fattahi, R., Yazdani, D., & Jafari, M. (2015). Chemical characterization of the essential oil compositions from Iranian populations of *Hypericum perforatum* L. *Industrial Crops and Products*, *76*, 565-573.

Morshedloo, M. R., Maggi, F., Neko, H. T., & Aghdam, M. S. (2018). Sumac (*Rhus coriaria* L.) fruit: Essential oil variability in Iranian populations. *Industrial Crops & Products*, *111*, 1-7.

Nayebpour, N., & Asadi-Gharneh, H. A. (2019). Variability of fatty acids composition of wild sumac (*Rhus coriaria* l.) fruit. *Journal of Medicinal Plants*, *71*(18), 118-129.

Nozza, E., Melzi, G., Marabini, L., Marinovich, M., Piazza, S., Khalilpour, S., Dell'Agli, M., & Sangiovanni, E. (2020). *Rhus coriaria* L. Fruit Extract Prevents UV-A-Induced Genotoxicity and Oxidative Injury in Human Microvascular Endothelial Cells. *Antioxidants*, *9*, 292.

Olaiya, C., Ogunyemi, O., & Karigidi, K. (2015).

Biotechnological strategies for enhancing the nutritive and nutraceutical values of tomato (Solanum lycopersicon). *The Annals of "Dunarea de Jos" University of Galati. Fascicle VI Food Technology.*, *39*, 9-19.

Ostadrahimi, A., Ezzati, S., Bahadori, M. B., Molani-Gol, R., Attari, V. E., & Kia, E. M. (2025). Delivery of Sumac (*Rhus coriaria* L.) Extract in a Chewing Gum System and Its Functional, Textural, and Sensory Characterization. *Food Science & Nutrition*, *13*, 1-9.

Pakseresht, S., Hadree, J., & Sedaghat, N. (2023). Characterization of Active Cerish Fructan-Sumac Extract Composite Films: Physical, Mechanical, and Antioxidant Properties. *Food Science & Nutrition*, *11*(7), 4170–4182.

Panico, A., Cardile, V., Santagati, N. A., & Messina, R. (2009). Antioxidant and protective effects of Sumac Leaves on chondrocytes. *Journal of Medicinal Plants Research.*, *3*, 855-861.

Parsania, M., Rezaee, M. B., Monavari, S. H., Jaimand, K., Mousavi Jazayeri, S. M., Razazian, M., & Nadjarha, M. H. (2017) Evaluation of antiviral effects of sumac (*Rhus coriaria* L.) fruit extract on acyclovir resistant Herpes simplex virus type 1. *Medical Sciences*, *27*, 1-8.

Rad, A. H., Khaleghi, M., & Javadi, M. (2020). Sumac in food ındustry: a changing outlook for consumer and producer. *Journal of Food Technology & Nutrition Science*, *2*(1), 1-3.

Radmehr, B., & Abdolrahimzade, M. (2009). Antimicrobial effects of sumac (*Rhus coriaria* L.) extract in minced meat. *Planta Medica.*, *75*, 1068.

Rahideh, S.T., Shidfar, F., Khandozi, N. Rajab, A., Hosseini, S. P., & Mirtaher, S. M. (2014). The effect of sumac (*Rhus coriaria* L.) powder on insulin resistance, malondialdehyde, high sensitive C-reactive protein and paraoxonase 1 activity in type 2 diabetic patients. *Journal of Research in Medical Sciences.*, *19*(2014), 933-938.

Raodah, M., Al-Ali, A. Z. H., & Faleeha, H. H. (2014) The antioxidant and antimicrobial of Syrian sumac (*Rhus coriaria*) fruit extracts. *Journal of Natural Sciences Research.*, *4*, 36-40.

Rashid, T. S., Awla, H. K., & Sijam, K. (2018). Antifungal effects of *Rhus coriaria* L. fruit extracts against tomato anthracnose caused by *Colletotrichum acutatum*. *Industrial Crops and Products*, *113*, 391-397.

Ravindran, P., Pillai, G., & Divakaran, M. (2012). Chapter - Other herbs and spices: mango ginger to wasabi. *In: Handbook of Herbs and Spices*, 557–582.

Rayne, S., & Mazza, G. (2007). Biological activities of extracts from sumac (*Rhus* spp.): a review. *Plant Foods for Human Nutrition*, *62*, 165-175.

Reidel, R. V. B., Cioni, P. L., Majo, L., & Pistelli, L. (2017). Evolution of Volatile Emission in *Rhus coriaria* Organs During Different Stages of Growth and Evaluation of the Essential Oil Composition. *Chemistry &. Biodiversity*, *14*(11).

Sabzghabaee, A. M., Kelishadi, R., Golshiri, K., Ghannadi, A., & Badri, S. (2014). Clinical effects of Rhus coriaria fruits on dyslipidemia in adolescents: a triple-blinded randomized placebo-controlled trial. *Medical Archives.*, *68*, 308.

Sakhr, K., & Khatib, S.E. (2020). Physiochemical properties and medicinal, nutritional and industrial applications of Lebanese Sumac (Syrian Sumac - *Rhus coriaria*): A review. *Heliyon*, *6*(1), e03207.

Sayed-Ahmed, M. Z., Ahdy, A. M., Younis, E. E., El-Khodery, S. A., & Baraka, H. N. (2019). Comparative Effectiveness of Sumaq and Neem Extract Cream, Eniloconazole and Glycerine Iodine on Dermatophytosis in Arabian Horses: A Randomized Clinical Trial. *Tropical Animal Health and Production.*, *51*, 905–910.

Serafini, M., & Peluso, I. (2016). Functional Foods for Health: The Interrelated Antioxidant and Anti-Inflammatory Role of Fruits, Vegetables, Herbs, Spices and Cocoa in Humans. *Current Pharmaceutical Design.*, *22*, 6701–6715.

Tang, S. C., & Yang, J. H. (2018). Dual Effects of Alpha-Hydroxy Acids on the Skin. *Molecules*, *23*, 1-12.

Taşkıran, Z. G., Dündar, A., & Yıldız, H. (2023). Bitkisel Materyallerdeki Biyoaktif Bileşenlerin Ekstraksiyonunda Kullanılan Konvansiyonel ve Yeni Nesil Ekstraksiyon Yöntemleri. *Food Science and Engineering Research*, *2*(2), 50-58.

Tuzlacı, E. (2006). *Şifa Niyetine Türkiye' nin Bitkisel Halk İlaçları*. Alfa Yayıncılık.

Tuzlacı, E. (2011). *Türkiye Bitkileri Sözlüğü*. Alfa Yayıncılık.

Ünder, D., & Saltan, F. Z. (2019). Sumak ve Önemli Biyolojik Etkileri, Çukurova Tarım Gıda Bil. Der., *34*(1), 51-60.

Wang, S., & Zhu, F. (2018). Quality attributes of bread fortified with staghorn sumac extract. *Journal of Texture Studies*, *49*, 129-134.

Wieczorek, P. P., Hudz, N., Yezerska, O., Horčinová-Sedláčková, V., Shanaida, M., Korytniuk, O., & Jasicka-Misiak, I. (2022). Chemical Variability and Pharmacological Potential of Propolis as a Source for the Development of New Pharmaceutical Products. *Molecules*, *27*, 1-28.

Yu, O. Y., Zhao, I. S., Mei, M. L., Lo, E. C., & Chu, C. H. (2017). Dental biofilm and laboratory microbial culture models for cariology research. *Dentistry journal (Basel).*, *5*(2), 21.

Zannou, O., Pashazadeh, H., Galanakis, C. M., Alamri, A., & Koca, I. (2022). Carboxylic acid-based deep eutectic solvents combined with innovative extraction techniques for greener extraction of phenolic compounds from sumac (*Rhus coriaria* L.). *Journal of Applied Research on Medicinal and Aromatic Plants.*, *30*, 100380.

Zannou, O., Oussou, K. F., Chabi, I. B., Awad, N. M. H., Aïssi, M. V., Goksen, G., Mortas, M., Oz, F., Proestos, C., & Kayodé, A. P. P. (2023). Nanoencapsulation of cyanidin 3- *O*-glucoside: purpose, technique, bioavailability, and stability. *Nanomaterials*, *13*, 617.

Zannou, O., Oussou, K. F., Chabi, I. B., Alamou, F. Awad, N. M. H., Miassi, Y. E., Loké, F. C. V., Abdoulaye, A., Pashazadeh, H., Redha, A. A., Kpoclou, Y. E., Guclu, G., Koca, I., Selli, S., & Ibrahim, S. A. (2025). Phytochemical and nutritional properties of sumac (*Rhus coriaria*): a potential ingredient for developing functional foods. *Journal of Future Foods*, *5*(1), 21-35.

Zargaran, A., Zarshenas, M. M., Karimi, A., Yarmohammadi, H., & Borhani-Haghighi, A. (2013). Management of stroke as described by Ibn Sina (Avicenna) in the Canon of Medicine. *International Journal of Cardiology.*, *169*, 233-237.

Zhaleh, M., Sohrabi, N., Zangeneh, M. M., Zangeneh, A., Moradi, R., & Zhaleh, H. (2018). Chemical Composition and Antibacterial Effects of Essential Oil of *Rhus coriaria* Fruits in the West of Iran (Kermanshah). *Journal of Essential Oil Bearing Plants*, *21*(2), 493-501.

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Disaster and Emergency Foods: Development and Nutritional Strategies

Afet ve Acil Durum Gıdaları: Geliştirme ve Beslenme Stratejileri

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ABSTRACT

Disaster, as defined by the Disaster and Emergency Management Presidency of Türkiye (AFAD), refers to events of natural, human, or technological origin that affect a certain part or all of society, cause physical, social, and economic losses, and stop or interrupt ordinary life and activities. In situations such as fires, floods, earthquakes, avalanches, droughts, famine, and war, one of the duties of the state and non-governmental organizations is to meet the nutritional needs of affected communities. When people encounter emergencies, they experience various nutritional problems. Damage to roads, kitchens, and equipment, which are needed to meet food needs, as well as problems such as hygiene issues, leads to nutritional shortages. Canned or dry foods are often consumed in case of an emergency. However, in emergencies, low protein, fat, and carbohydrate intake can cause poor nutrition. The aim of producing emergency foods is to meet the daily energy requirement of 2100 kcal for an average individual under difficult conditions. These special formulas are preferable in the form of biscuits, crackers, and bars that are low in moisture, easy to consume, and will not pose a risk to food safety and human health. The aim of this study is to briefly review information about emergency foods and their packaging.

Keyword: Disasters, emergency foods, packaging selection, nutritional adequacy

ÖZ

Türkiye Afet ve Acil Durum Yönetimi Başkanlığı'na (AFAD) göre afet; toplumun belirli bir kısmının veya tamamının etkilendiği, fiziksel, sosyal ve ekonomik kayıplara sebep olan, olağan hayatı ve faaliyetleri durduran veya kesintiye uğratan doğa, insan veya teknolojik kaynaklı olaylar olarak tanımlamaktadır. Yangın, sel, deprem, çığ, kuraklık, kıtlık ve savaş gibi durumlarda devletin ve sivil toplum kuruluşlarının görevlerinden biri de etkilenen toplulukların beslenme ihtiyaçlarını karşılamaktır. İnsanlar acil durumlar ile karşılaştığında bir takım beslenme sıkıntıları çekmektedir. Gıda ihtiyacını karşılamaya yönelik yolların, mutfak ve ekipmanların zarar görmesi, hijyen gibi sorun oluşması beslenme sıkıntısına yol açmaktadır. Genelde acil durumlarda konserve veya kuru yiyecekler sıklıkla tüketilir. Ancak acil durumlarda düşük protein, yağ, karbonhidrat alımı zayıf beslenmeye sebep olabilir. Üretilen acil durum gıdaları ile zor şartlar altında olan ve günlük ortalama bir bireyin alması gereken 2100 kcal enerji ihtiyacının karşılanması hedeflenmektedir. Üretilen bu özel formüller düşük nemli, tüketimi kolay, gıda güvenliği ve insan sağlığı açısından risk oluşturmayacak bisküviler, krakerler ve barlar olarak tercih edilebilir. Bu çalışmada amaç, literatürde yapılmış olan bazı acil durum gıdaları ve bu ürünlerin ambalajlanması ile ilgili bilgileri kısaca derlemektir.

Anahtar Kelimeler: Afetler, acil durum gıdaları, ambalaj seçimi, beslenme yeterliliği

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Introduction

According to the Disaster and Emergency Management Presidency of Türkiye (AFAD), disasters are technological, human, or natural events that cause economic, physical, and social losses, disrupt normal life and human activities, and exceed the society's coping capacity (AFAD, 2025). Emergencies and extreme weather events, such as floods and droughts, are increasingly occurring as a result of climate change (Gupta et al., 2022). These events occur every year and affect millions of people (Saggu et al., 2023). Worldwide, more than 14,000 disasters have occurred, 41.4 million people have been displaced, and 4.4 billion people have been adversely affected by these disasters in the last 20 years (Zeng et al., 2024). A report by AFAD (2023) stated that in Turkey, there were avalanches (or extreme snow blizzards) (93), earthquakes (830, magnitude 4 and above), landslides (564), forest fires (1711), mining accidents (7), and floods (2028). On February 6, 2023, two of the most destructive earthquakes in Turkey occurred, with epicentres in Pazarcık, Kahramanmaraş, and Elbistan, Kahramanmaraş. The earthquakes had magnitudes of Mw 7.7 and Mw 7.6, observed at 04:17 and 13:24, respectively. Many people lost their lives (Deprem Dairesi Başkanlığı, 2023). One of the first tasks of governments after disasters, which occur frequently worldwide and significantly affect lives, is to meet nutritional needs. Portions should be sufficient and balanced to provide the energy a person needs. If kitchen equipment is damaged in disaster-affected areas, a mobile kitchen is set up so that the meals are sufficient to meet the needs and reach every person. In disaster situations, non-perishable foods such as canned food, biscuits, and crackers are generally preferred. However, these products may not provide adequate nutrition; therefore, developing special formulations for disaster situations may be a good option. Emergency food formulas (EFF) provide the protein and calories required to support the body in emergency situations and during intense activity (Aydın et al., 2024). An example of this is biscuits, produced by Eti company, enriched with vitamins and minerals, and developed to be used in natural disaster situations. The aim of these products, produced as a social responsibility project by Eti, is to meet more than 30% of the calories that people will need in case of a possible disaster and to determine the utilization rate of 11 different vitamins and minerals, such as iron, zinc, and vitamin D. In addition, they established that the storage period for emergency foods, an important criterion, is 24 months without loss of nutrients (Anonymous, 2023).

In the global context, a number of emergency food products are available for purchase. These include emergency 3600-calorie food bar (SOS Food Labs), Mayday emergency food bars (Mayday Industries Store), and Mainstay emergency food rations (Amazon). The Rations emergency 3600-calorie product has received positive feedback from consumers, who have noted its favorable taste, durable and robust packaging, and a shelf life of 5 years.

In Turkey, in addition to the Eti company products, emergency foods are available under the Akana and Tada brands. Furthermore, there are products such as protein bars, canned foods, and pre-packaged items, with reinforced formulas available for purchase. However, research conducted following the 2023 earthquake revealed issues with nutrition. The Turkish Red Crescent provided menus for general, search and rescue, diabetes, and celiac needs. The general menu was found to be deficient in vitamin C, vitamin K, vitamin D, potassium, and calcium, nutrients to be consumed daily by earthquake victims (Günalan et al., 2024). The average daily intake of vitamin E, sodium, iodine, and phosphorus exceeded the recommended levels. The absence of vitamin C and vitamin D in the diet, in addition to the high omega-6/omega-3 ratio, has the potential to trigger inflammatory responses, compromise immune system function, and elevate the risk of infectious diseases (Günalan et al., 2024). In the research conducted in the aftermath of the earthquake in the Malatya, Adıyaman, and Kahramanmaraş-Pazarcık regions, 45 individuals employed in the Red Crescent were interviewed, with the participants reporting a lack of variety in the menus, which generally consisted of legumes, refined grains, spices, oils, fats, sweets, and sugary beverages. The majority of the staff stated that they were unable to incorporate vegetables, fruits, eggs, and dairy products into the menu. The reasons cited for this were cold weather conditions, organizational issues, stock shortages, and transportation difficulties (Alataş & Arslan, 2024). Nutrition, being a direct contributor to health, assumes even greater importance in disaster situations. Considering these findings, the formulation of novel nutrition-related plans for disaster situations in Turkey could potentially avert malnutrition in such circumstances.

The aim of this study is to compile products developed for emergencies and to provide brief information about the packaging materials used in these products.

Importance and support of nutrition in emergency situations

If the population affected by the disaster is completely dependent on food aid from outside, the prepared food ration should be at least 2100 kcal per person per day. However, if the population is already malnourished and exposed to cold, 100 kcal more should be added to the nutrition plan with every 5 °C temperature decrease (Singh, 2010). It is difficult to provide affected people with safe and sufficient food at the right time and place for a sustainable and healthy diet (Bounie et al., 2020). Emergencies have a significant impact on the population in terms of health issues such as disease and nutrition, more than on other aspects of daily life. After the 2011 Great East Japan earthquake, researchers showed that cardiovascular diseases increased (Aoki et al., 2012), as did hypertension (Ohira et al., 2016). The study conducted on pregnant individuals after the 2023 earthquake in Turkey found that their diet was deficient in essential macronutrients such as protein and various vitamins and minerals, particularly among those living in shelters. It was stated that nutritional deficiency, including calcium and vitamin D deficiency experienced by pregnant women, may increase the risk of infant rickets and osteoporosis in mothers, as well as the possibility of premature birth and low birth weight (Kaçar et al., 2024). Lipid-based, or powdered micronutrients can be effective in addressing problems of prolonged nutritional deficiencies after disasters. A report has been prepared on the use of lipid-based nutritional supplements to improve nutritional adequacy in vulnerable groups (pregnant women, children, and breastfeeding women) (Chaparro & Dewey, 2010). Here, lipid-based dietary supplementation is broadly defined as fortified nutritional structures, including both ready-to-use therapeutic foods with relatively low micronutrient concentrations, and high-concentration supplements (1-4 teaspoons/day, providing <100 kcal/day). The aim of these specialized formulations is to supplement nutrition with micronutrients such as calcium, iron, and vitamins that are deficient during emergencies. The report suggests that lipid-based nutritional supplements can improve the overall nutrition of the affected population (Chaparro & Dewey, 2010). Nutrition is essential for people, playing a vital role in protecting physical and psychological health. Considering the studies mentioned above demonstrate that nutritional interventions targeting human health yield positive results. However, the consequences of using these uniform and lacking diversity foods should not be ignored. It should be noted that long-term consumption of ready-to-eat foods may lead to a lack of essential nutrients, low fibre consumption, high salt and sugar intake, and, as a result, digestive disorders such as loss of appetite and constipation (Ainehvand et al., 2018).

Products for emergencies

EF is a special food prepared for use in emergency situations to meet the daily energy requirement of 2100 kcal/day. This food contains 35-45% fat, 10-15% protein, and 40-50% carbohydrate (Afifah et al., 2022). EF products should be designed as durable items with a long shelf life. Shelf-life testing determines the quality of foods during storage. This process may take a long time in actual storage conditions. For this reason, the universally accepted accelerated shelf-life test is used and when successfully applied, gives accurate results regarding the shelf life of the product (Calligaris et al., 2019). EF producers can save time by using the accelerated shelf-life test and by considering the relationship between parameters such as storage conditions and temperature.

In the process of developing a successful EF, the five characteristics to consider are safety, palatability, ease of distribution, ease of use, and nutritional completeness. (Medicine, 2002). For example, in one study, cereal flour (such as Hanjeli and Maize), tubers (such as Cassava and Sweet Potato), pulses (such as Garut and Mung Bean), and freshwater fish (such as Tilapia and Catfish) were used to produce EF in the form of cookies and food bars. The results showed that the cookies and food bars met the EF requirements, especially in terms of total calorie content (248.54-252.82 kcal/50 g), with fat content of (44.20-47.92%), carbohydrate content of (44.50-48.70%), and protein content of (7.10-7.90%), The products were reported to contain high levels of iron (2.63-3.85 mg), zinc (1.28-1.79 mg), and calcium (190.05-231.06 mg) per 50 g, and were intended to meet the nutritional needs of disaster victims. The products were preferred by the panelists based on the parameters of colour, aroma, taste, and texture. Each of these parameters received a score with a value above 4.5 on a 1-7 scale (Sumarto et al., 2023). Nutrition is especially critical for vulnerable groups, including the elderly and children, during natural disasters. It is emphasized that the consumption of nutrient-dense foods is an effective approach to improve the nutritional status of the elderly. Food intervention studies in the form of snacks and meals, including home-delivered meals, provided to malnourished elderly people, improve their nutritional status. In a study by Fatmah et al. (2021), broccoli-soybean-mangrove food bars were prepared to meet the nutritional needs and support weight gain of the elderly in disaster situations. Each 100 g broccoli-soybean-mangrove food bar has 492 kcal of energy, 60.4 g of carbohydrate, 3.8 g of protein, and 24.2 g of fat. Broccoli-soybean-mangrove food bars have been reported, containing complete macronutrients. They can serve as a source of nutrition for elderly people for only 15 days after disasters. Food bar production, like other well-known energy food products, attracts attention. Bars are usually prepared using products such as rice, oats, corn, milk and milk proteins, soya, and whey. To strengthen the nutritional content, the bars are fortified with vitamins, minerals, or other nutritionally rich ingredients. Bars are popular products in terms of both easy portability and health effects (Constantin & Istrati, 2018). Table 1 summarizes the EF products in the literature. According to the literature, soya flour was used in almost all studies. Soybeans are preferred because they have a high protein content of 34.8% and fibre content of 3.2% per 100 g (Adelakun et al., 2012); they are frequently chosen to strengthen the nutritional content of food formulations (Afifah et al., 2022). High levels of phytochemicals (flavonoids, phenolic content, and antioxidants) and probiotics can be added to prepared foods, in addition to providing energy, to increase immunity and overcome nutritional deficiencies, (Saggu et al., 2023). In one study, banaris bars were produced from sweet potato flour for toddlers and infants. The addition of prebiotics to these bars improved Lactobacillus populations in the body (Rachmat et al., 2019).

The focal point of the research is to ascertain the extent to which the products meet the recommended daily energy requirements and how consumers perceive and address cost issues. A thorough examination of the EP products reveals that they meet the daily energy needs of an individual. For instance, it has been documented that snack bars formulated with a blend of onggok, and cassava composite flour contain 11.06% protein, 1.24% ash, and 8.23% dietary fiber, thereby contributing to nutritional adequacy (Murdiani et al., 2022). Research conducted on refugee populations has demonstrated that the consumption of bars prepared using a flour mixture of banana, mung bean, and mung bean sprouts can satisfy daily nutritional requirements (Mahendradatta et al., 2020). Similarly, the consumption of emergency foods, in the form of cookies prepared from saba banana flour, soya flour, and moringa flour, has been shown to meet daily nutritional needs (Hasan et al., 2020). Although EF products meet energy needs, control samples are preferred in most studies. As the proportion of wheat flour in the content of ready-to-eat products prepared with cooked rice flour, roasted wheat flour, and Bengal gram flour increased, the sensory acceptability results became more positive (Dhami et al., 2019). The closer the products produced here are to traditional tastes and the more suitably they match the palate of the target segment, the more acceptable they are. While individuals tend to consume products that are palatable during disasters; when survival is paramount, the pursuit of flavour may become secondary. Conducting sufficient field studies on this subject, along with gathering information about environmental perspectives and the current stress on emergency foods, could yield valuable insights: into future planning. Considering the comprehensive review of all available information, it is imperative to prioritize the consumer's taste preferences, the safety and nutritional value of the products, the moisture content of the final product, and the selection of appropriate packaging when developing a novel emergency food product. Afterward, it is crucial to determine optimal storage conditions to ensure the safety of both the consumer and the products. Furthermore, it is essential to determine the most effective distribution routes and produce the product in a manner that minimizes cost. Furthermore, products can be produced and stored for individuals with special nutritional needs, such as phenylketonuria, lactose intolerance, and coeliac disease. Additionally, 3D printing models can be used.

Table 1.

Some emergency foods produced

Product types	Components used	Nutritional content of the final product	Research findings	References
EF	Maize flour,soya bean flour, tempe flour, milk powder, icing sugar, cooking oil	For 50 g of product Calorie:233 kcal Protein: 7,9-8,1 g Fat 9,1-11,9 g Carbohydrate 23-35 g	The water activity value of the products was found to be 0.93 and the products were considered microbially safe in weeks 1 and 2 but not in week 3.	Aini et al., (2018)
EF	Soya flour, whole milk powder, sunflower oil, oats, granulated sugar, sesame seeds, salt	For 439 g Calorie: 2194 kcal Protein: 70 g Sugar:158 g Dietary fibre :18 g Total fat: 196 g	Using linear programming helped to reduce the energy level, formulation development and cost of EF products.	Sheibani et al., (2017)
Bar	Black pepper, cinnamon powder, chickpea flour, dried apricot powder, milk powder, egg white, fennel, grated nutmeg, boiled rice flour, barley flour, pumpkin flour, chocolate and cardamom	For 100 g bar Calorie:339,61 kcal Protein: 9,45 g Fat: 6,86 g	It has been shown that bars with good results in terms of sensory properties such as aroma, taste, mouthfeel, texture and general acceptability can be a source of energy and nutrition.	Zahra et al., (2014)
Bar	Corn syrup, granulated sugar, high fructose corn syrup, crystalline fructose corn syrup, oil, lecithin, cellulose, bread flour, soya flour, soya concentrates	50 g for the bar Fat: 24,9 g Protein: 18,39 g Vitamin A: 370 ul/bar Foli acid: 80.7 µg/bar	The bars produced were acceptable, had low water activity and met the energy requirement as a formulation.	Brısske et al., (2004)
Bread	Wheat flour, soya flour, whey powder, skimmed milk powder, yeast, salt, water, egg powder and sunflower oil	For 100 g of bread Calorie: 242 kcal Carbohydrate:41,13 g Protein:8,33 g Total fat:4,88 g Dietary fibre: 2.22 g	The produced breads were subjected to gamma irradiation and microbiological analysis was carried out on the 1st, 7th, 25th, 40th, 40th, 52nd, 69th, 270th and 390th storage days and it was reported that the breads were microbiologically safe for 9 months.	González et al., (2017)
EF	Tapioca starch, ginger oil, water, tuna flour	For 100 g of product Calorie: 203.85 kcal Oil: 12,95 Protein: 15,45 Carbohydrate:64,94 Ash: 2.69	The water activity value was found to be 3.97 and it was reported that the products can meet the nutritional requirements.	Hasbullah et al., (2019)
Instant fish soup	Fish flour, tomato flour, cauliflower flour, sugar, salt, spices, corn flour	Soup containing 10% fish powder Carbohydrate: 65.7 Protein: 9.5 Fat: 1.47 Ash: 14	Soups containing 10% fish meal received the highest score for overall acceptability.	Rahman et al., (2012)
Bar	Nixtamalised corn flour, nike flour, corn starch, chocolate, margarine, egg white, sugar	For a 50 g bar: Calories: 234,92 kcal Protein:5,849 g Fat:9,89 g Carbohydrate:30,37 g	Different cooking temperatures were used, the liking score decreased with the use of nike flour, and the bars were reported to meet nutritional requirements.	Kasim et al., (2017)
instant cream soup	Beef broth, full cream milk powder, dried sweet potato puree, sugar, corn oil, pepper, salt, garlic powder	For approximately 1000 g Protein: 18%, Fat: 20.7%	It was stated by the panellists that the prepared cream soups could be used in emergencies and that the ready-made cream soups containing 20% whole milk powder had the best physical and chemical properties and were the most popular.	Sunyoto et al., (2018)
Ready-to-use therapeutic food (RUTF) spread	Soya flour, corn flour, milk protein concentrate, sugar, cocoa butter, vitamins and minerals, beta-alanine, arginine, Nigella sativa, sesame seeds	For 100 g RTUF Calorie: 525 kcal Carbohydrate: %45 Protein: %13 Fat: %42	Nutrient dense and sufficient RTUF is produced. There was no difference in sensory, physical, chemical properties and peroxide value of RTUFs stored at 38 C for 90 days with fresh samples.	Hadi et al., (2022)

Table 1.

(Continued)

EP	Whey protein nanofibrils, curcumin, quercetin, wheat flour, confectionery fat, sugar	Data not reported	Sensory acceptable, the addition of curcumin and quercetin significantly improved their antioxidant activity and suggested that these products could be used in the formulation of emergency food rations.	Mohammadiana et al., (2021)
Bar (PO-MU-MA)	Potato flour, mung bean flour, sugar, powdered milk, butter, baking soda	100 g for the bar Clorie: 461 kcal Protein: 8.30 g Fat: 22.69 g Carbohydrate: 56.25 g	It was found that the bars had low moisture content (11%), were microbially safe, sensory liked and could meet the nutritional needs.	Ibayan et al., (2024)
EF	Proso millet flour, snakehead fish-tempeh flour *koya*, sugar, margarine, skim milk, and egg	For 50 g of product Calorie: 249.83 kcal Protein: 16.85 %Fat: 19.74% Carbohydrate: 59.82% Ash: 3.59%	The most appreciated by the panellists in terms of crispness and colour was the sample with a ratio of 60% flour millet and 40% eel-tempeh koya.	Anandito et al., (2019)
EF (Food for disaster in accordance with Balinese culture)	Green beans powder, rice flour, peanuts, cashews, Moringa leaf powder, brown sugar	For 100 g of product Calorie: 433,27 kcal Protein: 16.41% Fat: 13.53% Carbohydrate: 61.48% Ash: 1.34% Food fiber 18.87%	It has been reported that the products are microbial safe for up to 10 days and 5 (50 g) portions are sufficient at the end of the correct portion selection. The formulations also received high scores in terms of general acceptability.	Agustini et al., (2022)
Bar	Cassava and red bean flour, skim milk powder, sugar and margarine	100 g gor the bar Calorie: 232.46 kcal Protein: 9.81g Fat: 19.37 Carbohydrate: 62.84 g Ash: 2.52 g	Bars prepared using cassava flour and red bean flour in the ratio 48:52 gave the best results in terms of organoleptic properties and colour.	Hadiningsih et al., (2023)
Bar	Shortening, wheat flour, skim milk powder, sugar, vanilla, cocoa powder, coconut powder, vitamins/minerals, salt, lecithin	Data not reported	The bars were coated with films prepared with whey protein isolate/κ-carrageenan (WC) and red grape pomace anthocyanins and stored at 38 C for 6 months. It was reported that EF can effectively improve the qualitative properties of products and may be an option for the packaging of oxygen-sensitive foods.	Yekta et al. (2024)

The nutritional content of the final product given in Table 1 and the results of the research represent the highest of the products produced.

Selection of packaging for EF products

Food packaging protects the quality and safety of food in the supply chain (Bumbudsanpharoke & Ko, 2022). The main consideration when estimating shelf life is the choice of packaging material (Alamri et al., 2021). Today, packaging materials, which are available at low cost, consisting of petrochemicals such as polyamide, polystyrene, polyethylene, polypropylene, polyvinyl chloride, and polyethylene terephthalate are widely used (Al-Tayyar et al., 2020). The packaging materials selected for EF products should be designed to be resistant to various levels of humidity and temperatures and distributed under difficult conditions. When determining the packaging material, one should consider that it will protect the vitamins, minerals, lipids, and protein content of the product, and provide long-term preservation. The packaging material should provide an effective barrier against moisture and oxygen transmission. High barrier polymers, such as ethylene vinyl alcohol or polyvinyl chloride, with sufficient thickness to protect products, can be very costly and may have a rough appearance. Metallised films, on the other hand, can provide moderate, but not sufficient, barrier properties for EF products. For these reasons, aluminium foil can be used, but it alone is brittle and prone to tearing. Polymer polyethylene terephthalate (polyester) and polyamides (nylon) can be coated on the outside of the foil by extrusion or adhesives; ideal packaging for EF products can be obtained (Lampi, 1977; Medicine, 2002). When noodles, a hygroscopic product, were packaged in low-density polyethylene, oriented polypropylene, double laminated, and triple laminated packaging materials, the shelf life of noodles increased up to 12, 19, 28, and 42 weeks, respectively (Navaratne, 2018). Another innovation in packaging is active packaging, which is designed not only to preserve food quality by performing additional functions but also to provide an inert barrier against the external environment. These packages constitute a packaging model that interacts with the product to extend shelf life or improve safety and sensory qualities (Fadiji et al., 2023). For example, energy bars produced for emergency situations are coated with a coating solution prepared with pomegranate peel extract, which has been shown to extend the shelf life of the products (Ghorbani et al., 2021). The production of EF noodles involved the utilisation of semolina flour, green tea, soy protein isolate, and spirulina powder. Shelf life was estimated based on organoleptic properties and water activity, followed by an investigation into microbial shelf life. It was determined that shelf life increases when products are stored in low humidity environments; and the inclusion of antioxidant components, such as those found in green tea, has the potential to exert a favourable effect on storage (Shahabinejad et al., 2024). The utilisation of smart packaging technology ensures traceability, quality, and safety of food products. This system assists decision-making by alerting users to potential issues and contributing to the maintenance of quality. The modified atmosphere packaging system is characterized as a food packaging technology based on mixtures of different gases (O_2, CO_2, N_2, etc.) depending on the product to be packaged. A study conducted by O'Connor et al. (2018) involved the preparation of sandwiches for the US military and packaging them in modified atmospheres combined with edible films. The results demonstrated an increase in shelf-life.

Conclusion and Recommendations

Nutrition is of paramount importance for survival in situations such as earthquakes, floods, tsunamis, avalanches, fires, droughts, epidemics, attacks, and wars. In the case of natural disasters, situations such as damage to roads, power, and water cuts, damage to kitchens, and problems in food supply are quite common. It is vital that both the disaster-affected individuals and search and rescue personnel have access to sufficient and balanced food. In light of these considerations, the strategic preparation and distribution of EF products emerges as a promising approach. The objective is to ensure the provision of products that meet the daily caloric requirement of approximately 2100 kcal per individual and provide adequate and balanced nutrients in terms of fat, protein, carbohydrates, and flavor, while ensuring a low moisture content, sensory acceptability, and extended shelf life. The paucity of research in this area is evident from the limited literature on the subject. This dearth of research is primarily attributed to the inability to capture traditional tastes and, more crucially, the cost implications. However, given the functionality of these products, there is a compelling rationale for conducting further research, particularly focusing on the needs of the elderly and children. Additionally, it is recommended that studies be conducted on gluten-free and lactose-free groups, who have specific nutritional requirements. The establishment of disaster warehouses in each region for the storage of these EF products is a proposed solution to address these issues. Future studies should focus on sensory acceptance, consumer preference, and, most importantly, extending the shelf-life of the product using smart packaging techniques.

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References

Adelakun, O. E., Duodu, K. G., Buys , E., & Ola, B. F. (2012). *Potential Use of Soybean Flour (Glycine max) in Food Fortification.* https://doi.org/10.5772/52599

AFAD *T.C. İçişleri Bakanlığı Afet Ve Acil Durum Yönetimi Başkanlığı.* 01 16, 2025 tarihinde https://www.afad.gov.tr/kurumlar/afad.gov.tr/e_Kutuphane/Istatistikler/2023yilidogakaynakliolayistatistikleri-_1_.pdf adresinden alındı

Afet ve Acil Durum Yönetimi Başkanlığı. *https://www.afad.gov.tr/aciklamali-afet-yonetimi-terimleri-sozlugu*.

Afifah, D. N., Ningrum, Y. P., Syahidah, T., Nuryanto, N., Ayustaningwarno, F., & Sugianto, D. N. (2022). Nutrient Content, Organoleptic Quality, and Shelf Life of Sagon Substitute From Lindur (Bruguiera gymnorrhiza L.) and Soybean Flour (Glycine max L.), as an Alternative Emergency Food. *Frontiers in Nutrition, 9*. https://doi.org/10.3389/fnut.2022.878539

Agustini, N. P., Puryana, G. P., & Mataram, I. A. (2022). Modification of Traditional Balinese Food as Disaster Emergency Food. *Jurnal Nutrisia, 24*(1), 40-47. https://doi.org/10.29238/jnutri.v24i1.268

Ainehvand, S., Raeissi, P., Ravaghi, H., & Maleki, M. (2018). The characteristic features of emergency food in national level natural disaster response programs: A qualitative study. *Journal of Education and Health Promotion, 8*(1). https://doi.org/10.4103/jehp.jehp_266_18

Aini, N., Prihananto, V., Wijonarko, G., & Sustriawan, B. (2018). Formulation and characterization of emergency food based on instan corn flour supplemented by instan tempeh (or soybean) flour. *International Food Research Journal, 25*(1), 287-292.

Alamri, M. S., Qasem, A. A., Mohamed, A. A., Hussain, S., Ibraheem, M. A., Shamlan, G., Hessam, A. A., & Qasha, A. S. (2021). Food packaging's materials: A food safety perspective. *Saudi Journal of Biological Sciences, 28*(8), 4490-4499. https://doi.org/10.1016/j.sjbs.2021.04.047

Alataş, H., & Arslan, N. (2024). Challenges in the food supply chain following the great earthquake disaster in Turkey: A study of the regions of Malatya, Adıyaman and Kahramanmaraş. *Journal of Education and Health Promotion*, *13*(1), 452. https://doi.org/10.4103/jehp.jehp_1961_23

Al-Tayyar, N. A., Youssef, A. M., & Al-hindi, R. (2020). Antimicrobial food packaging based on sustainable Bio-based materials for reducing foodborne Pathogens: A review. *Food Chemistry, 310*. https://doi.org/10.1016/j.foodchem.2019.125915

Amazon. (2025, 02 14). *amazon.com.tr*. emergency food bar: https://www.amazon.com/emergency-food-bar/s?k=emergency+food+bar retrieved from

Anonim. (2023). *Eti*. https://www.etietieti.com/vitamin-ve-minerallerle-zenginlestirilmis-biskuvi adresinden alındı

Anandito, Rbk, M. Oktaliana, Siswanti, and E. Nurhartadi. 2019. "Formulation of Emergency Food in Flakes Form Made from Proso Millet Flour (Panicum Milliaceum) and Snakehead Fish (Channa Striata)-Tempeh Flour Koya." *IOP Conference Series: Earth and Environmental Science* 246:012028. doi: 10.1088/1755-1315/246/1/012028.

Aoki, T., Fukumoto, Y., Yasuda, S., Sakata, Y., Ito, K., Takahashi, J., Miyata, S., Tsuji, I., & Shimokawa, H. (2012). The Great East Japan Earthquake Disaster and cardiovascular diseases. *European Heart Journal, 33*, 2796–2803. https://doi.org/10.1093/eurheartj/ehs288

Aydın, A., Yüceer, M., Ulugergerli, E. U., & Caner, C. (2024). Improving food security as disaster relief using intermediate moisture foods and active packaging technologies. *Applied Food Research, 4*(1). https://doi.org/10.1016/j.afres.2023.100378

Bounie, D., Arcot, J., Cole, M., Egal, F., Juliano, P., Mejia, C., Rosa, D., & Sellahewa , J. (2020). The role of food science and technology in humanitarian response. *Trends in Food Science & Technology, 103*, 367-375. https://doi.org/10.1016/j.tifs.2020.06.006

Brısske, L. K., Lee , S. Y., Kleın , B. P., & Cadwallader, K. R. (2004). Development of a PrototypeHigh-energy, Nutrient-denseFood Product for Emergency Relief. *Journal of Food Science, 69*(9), R181-C745. https://doi.org/10.1111/j.1365-2621.2004.tb09950.x

Bumbudsanpharoke, N., & Ko, S. (2022). Packaging technology for home meal replacement: Innovations and future prospective. *Food Control, 132*. https://doi.org/10.1016/j.foodcont.2021.108470

Calligaris, S., Manzocco, L., Anese, M., & Nicoli, M. C. (2019). 12 - Accelerated shelf life testing. *Food Quality and Shelf Life* (s. 359-392). https://doi.org/10.1016/B978-0-12-817190-5.00012-4

Chaparro, C. M., & Dewey, K. G. (2010). Use of lipid-based nutrient supplements (LNS) to improve the nutrient adequacy of general food distribution rations for vulnerable sub-groups in emergency settings. *Maternal & Child Nutrition,* *6*(1), 1-69. https://doi.org/10.1111/j.1740-8709.2009.00224.x

Constantin, O. E., & Istrati, D. I. (2018). Functional Properties of Snack Bars. *Functional Foods* (s. 1-14). https://doi.org/10.5772/intechopen.81020

Deprem Dairesi Başkanlığı. (2023). *06 Şubat 2023 Pazarcık (Kahramanmaraş) Mw 7.7 Elbistan (Kahramanmaraş) Mw 7.6 Depremlerine İlişkin Ön Değerlendirme Raporu.* T.C. İçişleri Bakanlığı Afet ve Acil Durum Yönetimi Başkanlığı. 1 1, 2025 tarihinde https://deprem.afad.gov.tr/assets/pdf/Kahramanmaras%20%20Depremleri_%20On%20Degerlendirme%20Raporu.pdf adresinden alındı

Dhami, P., Bains , K., & Kaur, H. (2019). Traditional Ready-To-Use Mix for the Food Basket of Calamity Stranded Evacuees – Analysis of Sensory, Nutritional and Storage Parameters. *Chemical Science Review and Letters, 8*(31), 100-109.

Fadiji, T., Rashvand , M., Daramola, M. O., & Iwarere, S. A. (2023). A Review on Antimicrobial Packaging for Extending the Shelf Life of Food. *Processes, 11*(2). https://doi.org/10.3390/pr11020590

Fatmah, F., Utomo, S. W., & Lestari, F. (2021). Broccoli-Soybean-Mangrove Food Bar as an Emergency Food for Older People during Natural Disaster. *International Journal of Environmental Research and Public Health, 18*.

Ghorbani, E., Moghaddam, A. D., Sharifan, A., & Kiani, H. (2021). Emergency Food Product Packaging by Pectin-Based Antimicrobial Coatings Functionalized by Pomegranate Peel Extracts. *Journal of Food Quality, 2021*(1). https://doi.org/10.1155/2021/6631021

González, G. S., Cova, M. C., Lires, C., Horak, C., Gómez, B., & Narvaiz , P. (2017). A highly nutritive bread, developed and gamma irradiated to serve in disaster relief or as an emergency ration. *Food Control, 72*, 338-344. https://doi.org/10.1016/j.foodcont.2016.04.027

Gupta, S., Modgil , S., Kumar , A., Sivarajah , U., & Irani , Z. (2022). Artificial intelligence and cloud-based Collaborative Platforms for Managing Disaster, extreme weather and emergency operations. *International Journal of Production Economics, 254*. https://doi.org/10.1016/j.ijpe.2022.108642

Günalan, E., Yoldaş, T., Turgut, R., Yenigün, A., Çavak, B. Y., & Parmaksız, A. (2024). Assessment of Nutritional Composition of Turkish Red Crescent Menus After the M7.8 and M7.6 Earthquakes in Kahramanmaraş, Türkiye. *Disaster Medicine and Public Health Preparedness*,*18*,e20.https://doi.org/10.1017/dmp.2024.16

Hadi, S., Amani, R., Tehrani, M. M., Hadi , V., Hejri, S., & Askari, G. (2022). Ready-to-Use Therapeutic Food (RUTF) Formulations with Functional Food and Nutrient Density for the Treatment of Malnutrition in Crisis. *International Journal of Preventive Medicine*, *13*(1). https://doi.org/10.4103/ijpvm.IJPVM_304_20

Hadiningsih, Naning, Irma Nuraeni, and Yanita Listianasari. 2023. "Formulation of Emergency Food Bars Made from Cassava Flour and Red Bean Flour." *Jurnal Gizi Dan Pangan* 18(Supp.1):84–86. doi: 10.25182/jgp.2023.18.Supp.1.84-86.

Hasan, N. W., Putri, T. P., & Zainal. (2020). Preparation of cookies from banana flour, soy flour, and Moringa leaf flour as an emergency food product. *IOP Conference Series: Earth and Environmental Science*, *486*(1), 012059. https://doi.org/10.1088/1755-1315/486/1/012059

Hasbullah, Rasulu, H., Albaar, N., & Mansour, N. A. (2019). The Use of Fishing Tuna Flour Fortification Modified Tapioca Starch in Emergency Food Product. *Advances in Engineering Research, 194*. https://doi.org/10.2991/aer.k.200325.049

Ibayan, L. M., Bauding, F. M., Cabading, M. P., Cayabyab, B. M., & Belino, P. B. (2024). PO-MU-MA Emergency food bar: nutritional, microbial, sensorial, and cost analysis. Brazilian Journal of Development, 10(6), 1-22. https://doi.org/10.34117/bjdv10n6-065

Kaçar, H. K., Kaçar, Ö. F., Kose, T., & Avery, A. (2024). The food and nutritional insecurity experienced by pregnant women living in shelters following the 2023 earthquakes in Turkiye. *nternational Journal of Disaster Risk Reduction, 114*. https://doi.org/10.1016/j.ijdrr.2024.104987

Kasim, R., Ahmad, L., Une, S., Bait, Y., & Liputo, S. A. (2017). Characterization of Snack Food Bars Made of Nixtamalized Corn Flour and Flour Of Nike Fish for Emergency Food. *International Journal of Agriculture*

System, 5(1). https://doi.org/10.20956/ijas.v5i1.1168

Lampi, R. A. (1977). Flexible Packaging for Thermoprocessed Foods. *Advances in Food Research* (Volume 23, p. 305-428). https://doi.org/10.1016/S0065-2628(08)60330-4

Mahendradatta, M., Laga, A., & Nurhisna, N. I. U. (2020). Study of snack bar combination of banana flour (Musa paradisiaca) and mung bean flour blending as emergency food. *IOP Conference Series: Earth and Environmental Science*, *486*(1), 012054. https://doi.org/10.1088/1755-1315/486/1/012054

Medicine, I. (2002). *High-Energy, Nutrient-Dense Emergency Relief Food Product.* USA: National Academies Press (US). https://doi.org/10.17226/10347

Mohammadiana, M., Moghaddam, A. D., Almasi, L., Bohlooli, S., & Sharifan, A. (2021). The enrichment of emergency food rations with complexes made of curcumin/quercetin-whey protein nanofibrils to improve their antioxidant activity. *Journal of Food and Bioprocess Engineering, 4*(1), 63-68. https://doi.org/10.22059/jfabe.2021.316882.1079

Murdiani, M., Kalsum, N., & Sarono, S. (2022). Formulation of Onggok Composite Flour Snack Bar (Manihot Esculenta) as Emergency Food Source of Protein. *Journal of The Community Development in Asia*, *5*(2), Article 2. https://doi.org/10.32535/jcda.v5i2.1499

Navaratne, S. B. (2018). Enhancement of food security through appropriate packaging to build up resilience for disasters. *Procedia Engineering, 212*, 55-60. https://doi.org/10.1016/j.proeng.2018.01.008

O'Connor, L. J., Favreau-Farhadi, N., & Barrett, A. H. (2018). Use of edible barriers in intermediate moisture food systems to inhibit moisture migration. *Journal of Food Processing and Preservation*, *42*(2), e13512. https://doi.org/10.1111/jfpp.13512

Ohira, T., Hosoya, M., Yasumura, S., Satoh, H., Suzuki, H., Sakai, A., Ohtsuru, A., Kawasaki, Y., Takahashi, A., Ozasa, K., Kobashi, G., Hashimoto, S., Kamiya, K., Yamashita, S., & Abe, M. (2016). Evacuation and Risk of Hypertension After the Great East Japan Earthquake: The Fukushima Health Management Survey. *Hypertension, 68*(3), 558-564. https://doi.org/10.1161/hypertensionaha.116.07499

Rachmat, R., Hastuti , W., & Darniadi, S. (2019). Characteristics of Snack Bar "Banaris" from Fortified Non Cereal Flour as Emergency Food for Toddler. *IOP Conf. Series: Earth and Environmental Science(2019)*, *309.* https://doi.org/10.1088/1755-1315/309/1/012058

Rahman, M. A., Saifullah , M., & Islam , M. N. (2012). Fish powder in instant fish soup mix. *AgEcon Search, 10*(1), 145-148. https://doi.org/10.22004/ag.econ.209310

Saggu, A. K., Tomer, V., Kumar , A., & Pandey, P. (2023). Consideration of Phytonutrients, Probiotics and Prebiotics for enhanced immunity during disaster relief situation – A review. *Clinical Nutrition Open Science, 47*, 131-146. https://doi.org/10.1016/j.nutos.2022.12.011

Shahabinejad, F., Ghorbani, M., Abbaszadeh, S., Nejatian, M., & Taghdir, M. (2024). Functional instant noodle formulation for emergency conditions: Sensory and stability characteristics. *Food Science & Nutrition*, *12*(7), 4605-4614. https://doi.org/10.1002/fsn3.4062

Sheibani, E., Moghaddam, A. D., Sharifan, A., & Afshari, Z. (2017). Linear programming: an alternative approach for developing formulations for emergency food products. *Journal of the Science of Food and Agriculture, 98*(4), 1444-1452. https://doi.org/10.1002/jsfa.8612

Singh, S. N. (2010). Nutrition in emergencies Issues involved in ensuring proper nutrition in post-chemical, biological, radiological, and nuclear disaster. *Journal of Pharmacy and Bioallied Sciences, 2*(3), 248-252. https://doi.org/10.4103/0975-7406.68507Sumarto, Radiati, A., Aprianty, D., Nuraeni, I., & Karimah, I. (2023). Development of emergency food products from varıous flour of cereals, tubers, pulses, and local freshwater fısh from ındonesıa. Asian Journal of Engineering, Social and Health, 2(3), 171-187.https://doi.org/10.46799/ajesh.v2i3.48

Sunyoto, M., Andoyo, R., & Dwiastuti, I. B. (2018). Characterıstıcs of sweet potato ınstant cream soup for emergency food. Jurnal Teknologi dan Industri Pangan, 29(2), 119-126. https://doi.org/10.6066/jtip.2018.29.2.119

Yekta, Reza, Arasb Dabbagh Moghaddam, Hedayat Hosseini, Anousheh Sharifan, Saeed Hadi, and Seyyed-Javad Hosseini-Shokouh. (2024). "Effect of Using Biodegradable Film Constituting Red Grape Anthocyanins as a Novel Packaging on the Qualitative Attributes of Emergency Food Bars during Storage." *Food Science & Nutrition* 12(4):2702–23. doi: 10.1002/fsn3.3951.

Zahra, S. M., Nadeem, M., Hussain, S., Qureshi, T. M., Din, A., & Rashid, F. (2014). Development and evaluatıon of nutrı-bars for ınternally dısplaced people ın humanıtarıan emergencıes. *Agricultural and Food Sciences, 52*(2).

Zeng, Y., Di, B., He, W., Wu, S., Li , J., Nienkotter , A., Li, O., & Peng, Q., Meng, X. (2024). Searching for emergency shelters in rural China: A systematicreview of policies and literature. International Journal of Disaster Risk Reduction, 115. https://doi.org/10.1016/j.ijdrr.2024.105017