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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of Hatay and Osmaniye hot red pepper paste processing wastes as capsaicin extracts (oleoresin)

Hatay ve Osmaniye acı kırmızıbiber salçası işleme atıklarının kapsaisin ekstraktı (oleoresin) olarak değerlendirilmesi

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ABSTRACT

This study aimed to evaluate the potential of red pepper paste waste from Hatay and Osmaniye (Türkiye) as a sustainable source of capsaicin. The samples were dried at 80 °C for 24 h, ground, and processed using a cold-press extraction method. Capsaicin, dihydrocapsaicin, total phenolic content, and antioxidant activity of the extracts were quantified by HPLC and spectrophotometric assays. The results revealed significant regional differences: Hatay samples exhibited markedly higher total phenolics (2758.81 mg GAE 100 g^{-1}), antioxidant capacity (71.41 µmol TEAC g^{-1}), and pungency (137,418 SHU) compared to Osmaniye (1921.19 mg GAE 100 g^{-1}; 49.76 µmol TEAC g^{-1}; 31,741 SHU).
The findings revealed that the pungency level of Hatay red pepper is similar to Habanero/Scotch Bonne/Jamaika pepper types. In contrast, Osmaniye pepper is identical to Aji Peru/Cayenne/Tabasco pepper types. The results indicate that red pepper waste can be considered as a sustainable resource for nutraceutical product development and the production of functional food ingredients, as well as for organic farming and other agricultural applications. Furthermore, the low-energy cold-pressing method used in this study offers both an environmentally sustainable and commercially viable approach to obtaining liquid oleoresin from waste material. The results scientifically demonstrate that waste from red pepper paste production is not simply an industrial byproduct but a valuable raw material source rich in capsaicin, phenolic compounds, and antioxidants.

ÖZET

Bu çalışmanın amacı, Hatay ve Osmaniye (Türkiye) kırmızıbiber salçası atıklarının sürdürülebilir bir kapsaisin kaynağı olarak potansiyelini değerlendirmektir. Örnekler 80 °C'de 24 saat kurutulmuş, öğütülmüş ve soğuk pres ekstraksiyon yöntemi kullanılarak işlenmiştir. Ekstraktların kapsaisin, dihidrokapsaisin, toplam fenolik madde içeriği ve antioksidan aktivitesi HPLC ve spektrofotometrik analizlerle belirlenmiştir. Sonuçlar, önemli bölgesel farklılıklar ortaya koymuştur: Hatay örnekleri, Osmaniye örneklerine (1921,19 mg GAE 100 g^{-1}; 49,76 µmol TEAC g^{-1}; 31.741 SHU) kıyasla belirgin şekilde daha yüksek toplam fenolik madde (2758,81 mg GAE 100 g^{-1}), antioksidan kapasite (71,41 µmol TEAC g^{-1}) ve keskinlik (137.418 SHU) sergilemiştir. Bulgular, Hatay kırmızıbiberinin arınma düzeyinin Habanero, Scotch Bonne ve/veya Jamaika biber türlerine, Osmaniye biberinin ise Aji Peru, Cayenne ve/veya Tabasco biber türlerine benzer olduğunu ortaya koymuştur. Sonuçlar, biber atığının nutrasötik ürün geliştirme ve fonksiyonel gıda bileşenlerinin üretiminin yanı sıra organik tarım ve diğer tarımsal uygulamalar için sürdürülebilir bir kaynak olarak değerlendirilebileceğini göstermektedir. Ayrıca, bu çalışmada kullanılan düşük enerjili soğuk presleme yöntemi, atık malzemeden sıvı oleoresin elde etmek için hem çevresel olarak sürdürülebilir hem de ticari olarak uygulanabilir bir yaklaşım sunmaktadır. Sonuçlar, acı biber salçası üretiminden kaynaklanan atıkların yalnızca endüstriyel bir yan ürün değil, kapsaisin ve diğer fenolik bileşikler ile antioksidanlar açısından zengin ve değerli bir hammadde kaynağı olduğunu bilimsel olarak kanıtlamaktadır.

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INTRODUCTION

Red pepper (*Capsicum* spp.) is an important raw material used in the food industry as both a spice and a processed product. Average annual production between 2020 and 2024 reached 1.1–1.3 million tons. By 2024, Türkiye, along with countries such as China, Mexico, and India, has been occupied the top five positions in global production, with a steady increase in production volumes observed, particularly in the last five years (Anonymous, 2025a; FAO, 2025; TUİK, 2025). Production is concentrated in the provinces of Şanlıurfa, Gaziantep, Mersin, Osmaniye, and Hatay, which are the main regions where varieties with high capsaicin content (red capia and chili peppers) are grown (Ayda et al., 2023; TUİK, 2025).

This high production volume brings with it the problem of large amounts of agro-industrial waste. The pulp (cake) waste generated during pepper paste production, in particular, requires a sustainable valorization strategy in terms of volume and environmental aspects (Shu et al., 2023). Although the seeds and shells (placenta), which constitute a large portion of pepper paste waste, are traditionally considered waste, they contain significant amounts of oil, protein, fiber, carotenoids, and, in particular, high concentrations of phenolic compounds and capsaicinoids. This rich bioactive profile highlights the potential for valorization as high-value-added functional food, feed, or bioadditive materials, rather than traditional waste disposal (Dobón-Suárez et al., 2025).

Capsaicinoids are vanillylamide alkaloids responsible for the characteristic pungency of hot red peppers. The majority of the total capsaicinoids in pepper fruit consist of capsaicin (about 69%) and dihydrocapsaicin (about 22%); these compounds are primarily synthesized in the fruit placenta and distributed to the seeds (Al Othman et al., 2011). Capsaicinoid ratios vary depending on genetic factors, environmental conditions, and processing methods (Zewdie & Bosland, 2000; Fornereto-Soldan et al., 2021). The pungency of peppers is usually expressed in Scoville Heat Units (SHU) or capsaicin concentration (mg L^{-1}) (Todd et al. 1977).

Capsaicinoids are at the center of scientific interest not only because of their sensory properties but also because of their extensive pharmacological and physiological effects (Yasin et al., 2023). Studies have shown that these compounds exhibit versatile biological activities, including antioxidant, antimicrobial, anti-inflammatory, analgesic, and anti-obesity effects (Krishnatreyya et al., 2018; Wang et al., 2021). Specifically, capsaicin acts on the nervous system, metabolic responses, and energy balance through its agonistic effect on TRPV1 (Transient Receptor Potential Vanilloid 1) receptors (Maharjan et al., 2024; Zhang et al., 2024). Furthermore, its anticancer (Kim et al., 2010; Luo et al., 2011), cardiovascular protective (Kawada et al., 1986; Srinivasan & Sambaiah, 1991), and mutagenicity-reducing (Deal et al., 1991) potentials increase the therapeutic value of capsaicin. Hot red peppers are rich not only in capsaicinoids but also in vitamins A, C, E, and the rare vitamin P (Duke, 1986). The synergistic effects of these components support the biological activity of capsaicin. Indeed, studies have reported that capsaicin has mutagenicity-reducing, tumour growth-inhibiting, and anti-inflammatory effects (Deal et al., 1991). In addition, capsaicin is used topically in rheumatic diseases due to its analgesic effect and to reduce the risk of cardiovascular disease by lowering cholesterol levels (Kawada et al., 1986; Srinivasan & Sambaiah, 1991).

Capsaicinoid content is significantly affected by genetic variations, environmental conditions, and processing parameters, particularly postharvest drying temperature, moisture content, and extraction method (Zewdie & Bosland, 2000; de Aguiar et al., 2016; Fornereto Soldan et al., 2021). The increasing global demand for capsaicin in the medical, cosmetic, and food sectors necessitates the search for low-cost, sustainable, and local raw materials as alternatives to traditional and synthetic production methods. In this context, it is believed that regional pepper paste waste can be considered a valuable alternative raw material source, thanks to its sustainable supply, offering a potential solution to the search for novel, eco-friendly, and economical resources due to its high capsaicinoid content.

This study aims to determine the chemical characterization and capsaicin production potential of pulp wastes from hot pepper paste production in Hatay and Osmaniye provinces, two of Türkiye's major red pepper production

regions. For this purpose, a capsaicin-containing liquid extract (oleoresin) was obtained, and the total phenolic content, antioxidant activity, and capsaicin and dihydrocapsaicin levels in the resulting oleoresin were determined. This study demonstrates the potential for transforming domestic pepper wastes into high-value-added products, providing an important scientific basis for both national waste management strategies and the development of the local nutraceutical industry.

MATERIALS and METHODS

Raw Material Supply and Preliminary Processes

Hot pepper paste wastes from Hatay and Osmaniye provinces were used in the study. At least 1.5 kg of red pepper paste waste was provided from each region. The samples were dried in an oven (FN 500) at 80 °C for 24 hours to standardize the moisture content. This process is shown in Figure 1. After drying, the samples were transferred to a Lavion HC-1500Y grinder and ground until the product was homogeneously powdered. In order to perform capsaicin analysis, the liquid extract (oleoresin) of the sample had to be obtained. The homogenized product was pressed with a Koçmaksan MKS10 cold-press seed extrusion machine to obtain oleoresin. The steps of obtaining oleoresin by the cold pressing method are presented in Figure 1.



Figure 1**.** Obtaining Oleoresin from Ground Red pepper by Cold Pressing Method
Şekil 1. Soğuk Presleme Yöntemiyle Öğütülmüş Kırmızıbiberden Oleoresin Elde Edilmesi

For the determination of capsaicin and antioxidant activity in oleoresin samples, approximately 5g of the oleoresin sample was taken, and methanol (or ethanol) was added to it at a ratio of 1:10. The extraction process was then carried out on a shaker for 20 minutes. At the end of this period, filtration was performed. The final volume of the filtered sample was determined and stored in the refrigerator at +4°C to be used in the determination of total antioxidant activity.

Capsaicin, Dihydrocapsaicin and SHU analyses

For capsaicin and dihydrocapsaicin quantification, samples were passed through a 0.45 µm PTFE filter and placed in 2 ml volume HPLC vials. An HPLC (Shimadzu, Prominence Modular LC20A HPLC) system with an ultraviolet (UV) detector and a C18 column (Hypersil ODS, C18, 5 µl, 4.6×250 mm) were used for analysis. An isocratic mixture containing 48.4% methanol, 30.2% water, 13.3% dioxane, 7.9% acetonitrile and 0.2% perchloric acid (2%) was used as the mobile phase (Fırat et al., 2021; Erol et al., 2024).

The injection volume was set at 10 µL, the detection wavelength at 280 nm, the analysis time at 20 minutes, and the mobile phase flow rate at 1 ml min^{-1}. Before analysis, calibration curves were prepared from capsaicin and dihydrocapsaicin standard solutions. Red pepper oleoresin samples were read into the HPLC device and compared with these calibration curves to calculate the capsaicin and dihydrocapsaicin amounts in mg kg^{-1}. Chromatograms

showing the capsaicin and dihydrocapsaicin amounts are given in the results. When determining the amount of *pungency*, the SHU value was calculated according to the following equation (Eq. 1).

$$Pungency\ (SHU) = (Capsaicin + (0.82 \times Dihydrocapsaicin) \times 16 \qquad Eq\ 1$$

Pungency (*SHU*) unit was evaluated according to the "Scoville Heat Unit (SHU)" chart developed by Wilbur Scoville and given in **Appendix –Figure 1**. This colorimetric method is a practical method for determining the pungency level (Al Othman et al., 2011; Ahmad et al., 2020).

Determination of total phenolic substances and antioxidant activity amounts

Total phenolic content of red pepper extracts was determined using the Folin-Ciocalteu method according to the method proposed by Castro-Concha et al. (2014). Briefly, 2.5 ml of diluted Folin-Ciocalteu reagent (1:10 v/v) was added to 0.5 ml of extract solution in methanol. After 5 min, 2 ml of sodium carbonate solution (7.5%) was added and the mixture was left to stand for 2 h at room temperature in the dark. Absorbance was measured at 760 nm using a spectrophotometer (Biochrom brand, Libra S70 model). Gallic acid was used as a standard and results were expressed as milligrams of gallic acid equivalents per 100 grams of a sample (mg GAE $100g^{-1}$).

Antioxidant activity was determined spectrophotometrically using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method. Analysis results were expressed as Trolox equivalent antioxidant capacity (µmol TEAC g^{-1}). For this purpose, a calibration curve was created using Trolox standard solutions prepared in the 0.1–1.0 mM concentration range. By fitting the absorbance values of the samples to this curve, antioxidant capacities were calculated in µmol Trolox equivalents/g sample. Measurements were performed using a UV-VIS spectrophotometer at a wavelength of 517 nm.

For the determination of antioxidant activity, oleoresins, previously separated and stored at +4°C, were prepared for analysis by diluting them 1:10 with 70% methanol. 0.1 mL of each sample was mixed with 3.9 mL of DPPH solution (0.1 mM, prepared in methanol). After the mixture was left in the dark for 30 minutes, absorbance values were measured with a UV-VIS spectrophotometer at 517 nm wavelength. Radical scavenging capacity was calculated using the following formula (Eq. 2):

$$\%\ Inhibition = \left(\frac{A_{Control} - A_{Sample}}{A_{Control}}\right) * 100 \qquad Eq\ 2$$

Here, the $A_{Control}$ is the absorbance of the solution containing only DPPH; the A_{Sample} is the absorbance of the solution with added oleoresin. Each sample was run in triplicate, and the average values are reported (Fornereto Soldan et al., 2021).

Statistical Analysis

The data obtained were calculated as the average of three repeated measurements, and the means and standard deviations were calculated with the Microsoft Excel program. The results obtained are presented in Table 1.

RESULTS and DISCUSSIONS

Capsaicin, Dihydrocapsaicin, and Pungency (SHU) Profile

Total phenolic content determination results showed that the oleoresin from red peppers from Hatay was higher than that from Osmaniye. The chromatographic profiles of the samples are presented in Figures 2 and 3. Comparison of the chromatograms showed that the capsaicin and dihydrocapsaicin peaks in the Hatay sample had significantly higher signal intensities than in the Osmaniye sample. This higher efficiency is also due to the

concentration of capsaicinoids (Maharjan et al., 2024) and other phenolic compounds (Dobón-Suárez et al., 2025) in the seeds and peels, which constitute a large portion of pulp waste.

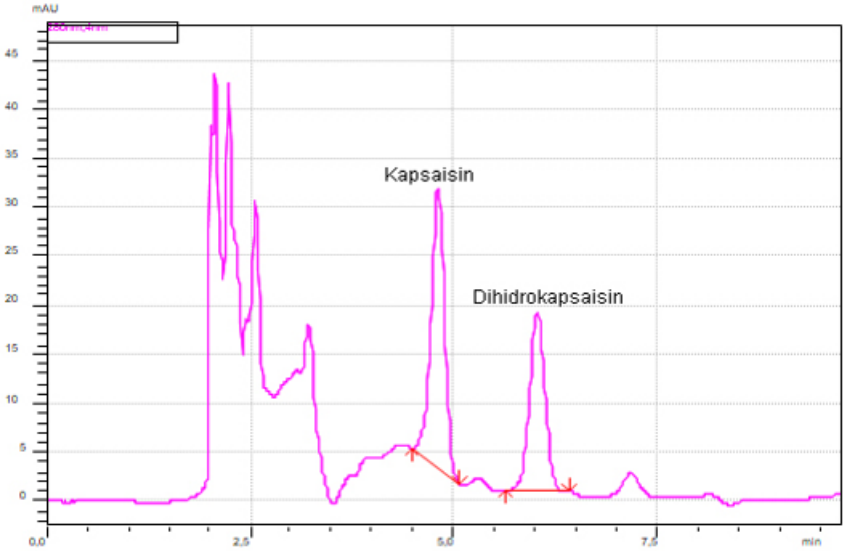


Figure 2. Results of phenolic substance determination obtained from the oleoresin of Hatay red pepper paste wastes

Şekil 2. Hatay kırmızıbiber salçası atıklarından elde edilen oleoresinlerden elde edilen fenolik madde tayini sonuçları

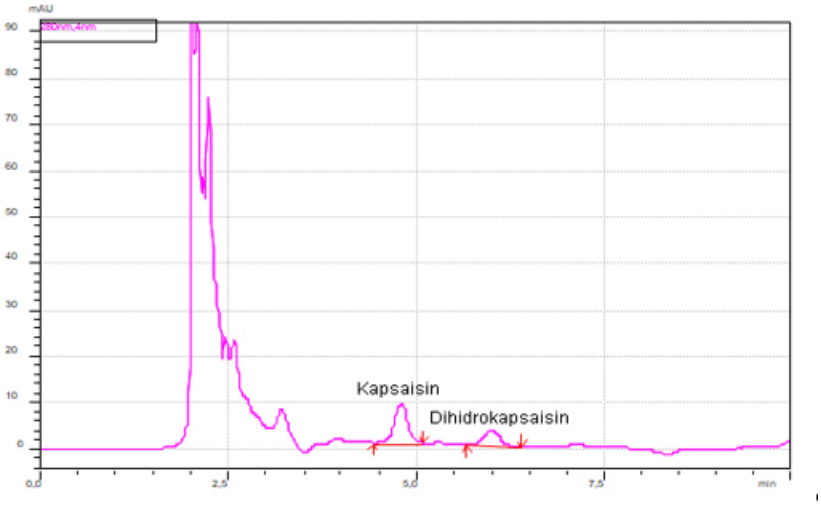


Figure 3**.** Results of phenolic substance determination obtained from the oleoresin of Osmaniye red pepper paste wastes

Şekil 3. Osmaniye kırmızıbiber salçası atıklarından elde edilen oleoresin'den elde edilen fenolik madde tayini sonuçları

Regional differences should be attributed not only to genetic variation, but also to processing parameters such as fermentation and drying time in local pepper paste production, affecting the rate of preservation of bioactive compounds in the waste. Studies conducted particularly on fermented pepper paste show that the process applied in paste production directly affects the concentration of capsaicin and dihydrocapsaicin in the final product and therefore in the waste (Wu et al., 2019). This is consistent with the knowledge that pungency is affected by

environmental factors and cultural practices (Arın, 2018). The results of chemical analysis of red pepper paste waste are presented in Table 1.

Table 1**.** Composition of oleoresins obtained from red pepper paste waste
Çizelge 1. Kırmızıbiber salçası atıklarından elde edilen oleoresinlerin bileşimi

Sample	Total Phenolic Substance (mg GAE $100g^{-1}$)	Antioxidant Activity (µmol TEAC g^{-1})	Capsaicin (mg kg^{-1})	Dihydrocapsaicin (mg kg^{-1})	SHU
Osmaniye	1921.19 ± 0.06	49.76 ± 0.04	1564.95 ± 0.03	512.32 ± 0.05	≈ 31741
Hatay	2758.81 ± 0.09	71.41 ± 0.05	5758.80 ± 0.07	3451.08 ± 0.06	≈ 137418

According to the results of capsaicin and dihydrocapsaicin quantification, the pungency value obtained from Osmaniye red pepper was determined as ≈31741 SHU, while the pungency value obtained from Hatay red pepper was determined as ≈137418 SHU. This shows that the pepper from Hatay has a sharper level of pungency. Furthermore, when these values are compared with other types of peppers' pungency level, Osmaniye red pepper has a similar pungency to Aji Peruvian/Cayenne/Tabasco pepper types, Hatay red pepper has a similar pungency to Habanero/Scotch Bonnet/Jamaican pepper types (See Appendix - Figure 1).

Capsaicin, found in peppers, is known to facilitate digestion by positively affecting intestinal and stomach movements (Bozokalfa & Eşiyok, 2011). Furthermore, it has been suggested that capsaicin is primarily responsible for the antimicrobial activity of peppers (Koffi-Nevry et al., 2012). This antimicrobial potential of capsaicin supports its use as a natural preservative in foods (Wang et al., 2021). Applications of oleoresin extracts in the food industry include increasing the nutritional value and functionality of fermented products such as yoghurt (Aşkın et al., 2022) or using them as nutraceutical raw materials. Additionally, the use of low-tech extracts in organic farming as pest repellents (Servent et al., 2025) or in agricultural practices (Arın, 2018) reinforces the environmental benefit of waste valorization.

CONCLUSION

This study demonstrated that hot red pepper paste wastes produced in Hatay and Osmaniye provinces have a high potential for capsaicin production. Oleoresin samples obtained by the cold-pressing method had a rich composition in terms of capsaicin and dihydrocapsaicin; both total phenolic substance and antioxidant activity levels were found to be significantly higher in Hatay samples compared to Osmaniye. This difference may be due to regional agronomic conditions, climatic characteristics, and processing parameters (drying temperature, fermentation time, humidity, etc.).

The low-energy cold-pressing method employed in this study offers an eco-friendly and commercially viable method for obtaining liquid oleoresin from waste material. The results demonstrate that waste from pepper paste production is not only an industrial byproduct but also a valuable raw material source for capsaicin, phenolic compounds, and antioxidants. In this context, the recovery of red pepper paste pulp offers an eco-friendly approach to waste management and provides a sustainable alternative for the biotechnological, nutraceutical, cosmetic, and food industries.

In conclusion:

- Pepper paste pulp, instead of being traditionally disposed of as waste, has the potential to be transformed into high-value-added products as functional food ingredients, nutraceutical raw materials, natural antioxidants, or antimicrobial agents.

- It offers a practical and economical valorization model that aligns with circular economy principles by reducing reliance on capsaicin imports and supporting the "waste → resource" transformation in the agro-industrial cycle.
- The resulting highly pungent extracts are particularly suitable for direct use in non-food and non-pharmaceutical sectors (e.g., topical analgesic cream formulations, natural pest repellent sprays).

Future studies focusing on advanced stages such as purification, microencapsulation, and formulation optimization of these extracts will strengthen Türkiye's domestic capsaicin production capacity. Furthermore, efforts should be focused on optimizing the effects of pepper varieties and traditional paste production parameters (fermentation time, drying temperature, etc.) on capsaicinoid yield to further elucidate the source of regional differences. This will unlock the full potential of waste derived from Türkiye's rich pepper gene pool.

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STATEMENT OF CONFLICT OF INTEREST

The authors declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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Scoville derecesi	Biber türü
15,000,000–16,000,000	Saf **Kapsaisin** (*n-vanillil-8-metil-6-(e)-noneamid*) (Kimyasal hali)
9,100,000	**Nordihidrokapsaisin** (kimyasal hali)
2,000,000–5,300,000	Birleşik Devletler standartlarına uygun **biber gazı**
1,500,000	**Caroline Reaper** - *Capsicum chinense* (Dünyanın en acı biberi)
855,000–1,041,427	**Naga Jolokia** - *Capsicum chinense* (Dünyanın 2. en acı biber meyvesi)
876,000–970,000	**Dorset Naga** - *Capsicum chinense*
350,000–577,000	**Red Savina™** - *Capsicum chinense*
100,000–350,000	**Habanero biberi** - *Capsicum chinense*
100,000–350,000	**Scotch Bonnet** - *Capsicum chinense*
100,000–200,000	**Jamaika Acı Biberi**
50,000–100,000	**Thai biberi**, **Malagueta biberi** - *Capsicum frutescens*, **Chiltepin biberi** - *Capsicum annuum*
30,000–50,000	**Cayenne biberi** - *Capsicum annuum*, **Ají Peru biberi** - *Capsicum baccatum*, **Tabasco biberi** - *Capsicum frutescens*
10,000–23,000	**Serrano biberi**
7000–8000	**Tabasco sosu** (Habanerolu)
5000–10,000	**Wax biberi**
2500–8000	**Jalapeno biberi** - *Capsicum annuum*
2500–5000	**Tabasco sosu** (Tabascolu)
1500–2500	**Rocotillo biberi**
1000–1500	**Poblano biberi** - *Capsicum annuum*
600–800	**Tabasco sosu** (Yeşil biberli)
500–1000	**New Mexico Anaheim biberi**
100–500	**Pimento biberi** (Tatlı kırmızı biber) - *Capsicum annuum*, **Pepperoncini** - *Capsicum annuum*
0-100	Acısız, **Dolmalık biber** - *Capsicum annuum*.

Appendix - Figure 1**.** Scoville Heat Unit (*SHU*) (Anonymous, 2025b)

Ek - Şekil 1. Scoville Acılık Birimleri (SHU) (Anonymous, 2025b)