The International Journal of Engineering and Science (IJES)
|| Volume || 15 || Issue 2 || February || Pages || PP 01-09 || 2026 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Evaluation of Drying Methods and Quality Characteristics of Red Pepper (Capsicum Annuum L.) from Traditional to Hybrid Systems

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ABSTRACT
Red pepper is an important agricultural product due to its high vitamin C, carotenoid, phenolic compound, and capsaicinoid content. However, the high moisture content after harvest causes microbial spoilage, shortening the product's shelf life. To prevent this, it has become necessary to use various drying methods. This review aims to evaluate the effects of different drying techniques on the product quality of red pepper. The evaluations revealed that sun drying, the oldest and most traditional method, has disadvantages such as long drying time and loss of product quality, despite its low cost. Hot air drying, despite its widespread industrial use, caused loss of aromatic compounds, a decrease in phenolic content, and a reduction in ascorbic acid content. In contrast, freeze-drying and vacuum-assisted microwave drying emerged as effective methods due to their ability to preserve color stability, high ascorbic acid content, and antioxidant properties. Hybrid systems have been found to significantly reduce drying time and increase energy efficiency. In summary, while freeze-drying and vacuum-assisted microwave systems are recommended for obtaining high-quality products, hybrid systems are recommended when evaluating speed and cost balance on an industrial scale.
KEYWORDS; *red pepper; Capsicum annuum; drying techniques; bioactive compounds; hybrid drying techniques.*

Date of Submission: 05-02-2026 Date of acceptance: 16-02-2026

I. INTRODUCTION

Pepper is a plant belonging to the Capsicum annuum L. family. There are different varieties in terms of morphology, taste, and pungency. These include bell peppers, stuffing peppers, pointed peppers, charleston peppers, and hot peppers (cayenne, jalapeno, etc.). Red pepper (Capsicum annuum L.) is an important agricultural product widely used both fresh and in dried form due to its high nutritional value, characteristic aroma profile, and bioactive compound content [1]. Carotenoids (especially capsanthin), phenolic compounds, ascorbic acid, and capsaicin are the key components that give peppers their red color, antioxidant capacity, and pungent taste profile [2]. Freshly harvested peppers typically contain high moisture content, which increases the risk of spoilage, microbial growth, and quality loss. Therefore, the drying process, although preferred as a preservation method, increases the value and marketability of the raw product [3].

Historically, for producers, the most cost-effective and widespread drying method has been sun drying; however, this method has significant disadvantages such as long drying times, risk of microbial contamination, dependence on climate, and quality variations [4]. Due to these disadvantages, scientific and industrial applications have shifted towards more controlled and rapid drying techniques. Studies conducted in the 2020s show that this transformation offers significant advantages, particularly in terms of energy efficiency, quality preservation, and process standardization [5].

Modern drying techniques include hot air drying, microwave drying, infrared (IR) drying, vacuum drying, freeze-drying, and various hybrid combinations of these methods (e.g., microwave + hot air, IR + hot air). These techniques have the potential to shorten drying time, reduce energy consumption, minimize tissue deformation, and limit color, aroma, and active ingredient losses. In particular, low-temperature and controlled drying processes (freeze-drying and vacuum drying) stand out in minimizing pigment and bioactive compound losses [2].

In contrast, high-temperature and prolonged drying (such as conventional methods like hot air) can result in darkening of the pepper's color, carotenoid degradation, and losses in phenolic content and aroma. For example, in one study, increasing the thermal drying time resulted in darkening of the surface color of red peppers, a decrease in red-yellow tones, and microstructural changes [2].

On the other hand, from the perspective of consumer expectations, simply removing moisture is not sufficient: it is important to preserve the color, aroma profile, nutritional value, and rehydration properties of dried peppers. Therefore, it is necessary to select the drying method and optimize the controlled parameters. In this context, the literature frequently emphasizes that low temperature + controlled drying (vacuum, freeze-drying), microwave or IR-assisted rapid drying, and hybrid methods offer balanced performance [5].

This review aims to comprehensively evaluate traditional and modern techniques used in drying red peppers (hot air, microwave, IR, vacuum, freeze-drying, hybrid systems) and to comparatively analyze their performance in terms of product quality (color-pigment stability, aroma and volatile compounds, bioactive compounds) and drying time. This study aims to contribute to the academic literature and provide a practical guide for industrial practitioners.

II. OVERVIEW OF RED PEPPER

Applications of red pepper

Due to its rich content, red pepper is used in many areas both fresh and dried. Fresh and dried red peppers are frequently used in many types of dishes to enhance flavor and aroma. In industrial operations, it is used in canning, sauce and ketchup production, and ready-made meals (soups, sauces, etc.), as well as in spice blends and deli products to add color and aroma. Due to the antioxidant properties of capsaicin and carotenoids in its content, it is also preferred in the health sector as a supplement or functional food additive [6], [7].

Production of red pepper in Turkey and worldwide

Red pepper varieties are quite diverse worldwide and in Turkey. Turkey has a rich range of agricultural products thanks to its geographical location and climate diversity. The Mediterranean, Aegean, and Marmara regions account for approximately 80% of total pepper production. The most commonly produced pepper varieties in Turkey are bell peppers, pointed peppers, charleston peppers, stuffing peppers, and hot peppers. These peppers are grown both fresh and for drying and occupy an important place in both the Turkish and global markets due to their high yield and durability.

Globally, the largest producers of red peppers are China, Mexico, the USA, India, and South American countries. These countries have significant shares in both consumption and exports. According to 2022 FAO data, 36.97 million tons of peppers are produced worldwide each year. China stands out among other countries with a production of 16.8 million tons, followed by Mexico with 3.1 million tons, Indonesia with 3 million tons, Turkey with 3 million tons, and Spain with 1.5 million tons [8].

Turkey is the largest vegetable producer after China, India, and the United States. In recent years, vegetable production in Turkey has exceeded 31 million tons, and as of 2024, total pepper production is 3,428,038 tons, an increase of 11.3% over the previous year. Bell peppers account for 56.6% of Turkey's total pepper production, pointed peppers account for 27.2%, stuffing peppers account for 12.3%, and charleston peppers account for 3.9%. Turkey has secured an important place in the market not only in terms of production but also in terms of exports. Red pepper exports, which amounted to 21,830 tons in 2019, were recorded as 50,691 tons according to 2023 data. Germany and Bulgaria rank first among the exporting countries [9], [10].

Components of red pepper

100 grams of fresh red pepper contains 92 g of water, 6 g of carbohydrates, 1 g of protein, 0.3 g of fat, and has an energy value of 31 calories. Red pepper is rich in minerals such as K, Mg, and Ca, as well as vitamins A and C, and has low levels of saturated fat and sodium. 100 grams of fresh red pepper contains approximately 130 mg of vitamin C, which meets about 200% of the daily vitamin C requirement [11] The basic form of vitamin C is ascorbic acid, and the ascorbic acid content increases in direct proportion to the ripeness of the pepper.

Red pepper contains various carotenoid pigments such as capsaicin, β-carotene, and capsorubin, and is highly effective in eliminating free radicals due to its antioxidant properties [12]. The active ingredients in red pepper are capsaicin and capsaicinoids. These active ingredients give red pepper its pungent taste [13].

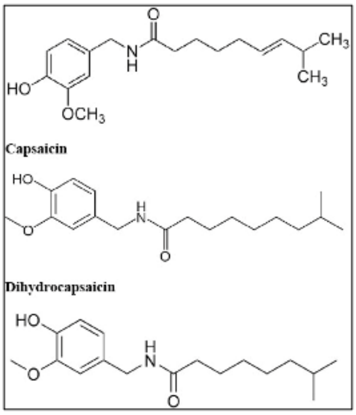

Figure 1. Chemical structure of capsaicinoids

Red pepper contains phenols such as quercetin and luteolin, in addition to vitamin C and carotenoids. These phenolic compounds form an important phytochemical group due to their free radical scavenging properties, and the amount of these compounds varies depending on the development and ripening process [14].

Red pepper in the field of health

Colored fruits and vegetables are important for health due to their vitamin, mineral, and bioactive content, and their daily consumption is recommended. Red pepper is a prominent food due to its important vitamin and mineral content and antioxidant properties. It plays an important role in health with its vitamin A content of 101mg/100 g RE, riboflavin content of 0.122 mg/100 g, vitamin C content of approximately 150.7 mg/100 g and lutein content of 381 µg/100g [15].

Red pepper has been used in traditional medicine not only for the treatment of conditions such as cough, toothache, sore throat, rheumatism, and parasitic infections, but also as an antiseptic, appetite stimulant, irritant reliever, antioxidant, and immunomodulator [16], [17], [18]Red pepper is used as a medicine for bloating and atonic dyspepsia because it increases motility in the gastric antrum, duodenum, proximal jejunum, and colon [17], [18]. Its leaves also have antioxidant activity [19]. One study found that fermented red pepper paste reduced total cholesterol and LDL-C cholesterol levels [20]. In an in vitro study, it was observed that hot peppers can moderately transactivate the PPARα transcription factor in NTH-3T3 cells, thereby helping to increase HDL and lower TG levels, ultimately improving the lipid profile [21]. Thus, it can be predicted that red pepper has a regulatory effect on HDL, LDL, and especially total cholesterol levels.

III. DRYING TECHNIQUES

Hot Air Drying

Hot air dryers have a closed operating system where heated air circulates within the system. Hot air drying is a classic drying method commonly preferred for agricultural products. Its basic mechanism is;
Convective heat transfer + diffusive mass transfer

Advantages

Simple equipment
Widespread industrial use
Low investment cost

Disadvantages

Long drying time
Color loss
Loss of aromatic compounds
Decrease in vitamin C and phenolic compound content

Freeze-Drying (Lyophilization)

Freeze drying is a drying technique used primarily in the food industry for the preservation and production of food, as well as in the pharmaceutical industry for drug production [22], [23].

Advantages

Color and aroma preservation
Porous structure (high rehydration capacity)

Disadvantages

Long drying time
High cost
High energy consumption

Microwave Drying Microwave Drying

In the microwave drying method, water molecules within the material are directly targeted and a selective heating process is performed [24]. Thus, heating occurs from the inside out. Like other techniques, this technique has both advantages and disadvantages. It is generally preferred to use it in combination with other drying techniques.

Advantages
One of the fastest drying methods
Formation of a porous structure
Color preservation
High energy efficiency

Disadvantages
High investment cost
Loss of aroma in the product
Requires special design

Infrared (IR) Drying

Infrared drying can be considered an artificial form of natural drying by the sun. The electromagnetic radiation sent to the product surface is absorbed by the material and increases internal molecular vibrations, generating heat and thus causing moisture to evaporate [25].

Advantages
Fast drying
High energy efficiency
Homogeneous heating
Easy control of material temperature

Disadvantages
The product's structural properties may be compromised
Limited applicability (thickness issue)

Vacuum Drying

Vacuum dryers are based on the principle of drying the sample at low pressure and evaporating the moisture in the material at lower temperatures. This drying method is used for heat-sensitive materials and materials that are sensitive to changes in color, appearance, nutritional content, and vitamin content [26].

Advantages:Low-temperature drying:Rapid drying;Minimal oxidation; Easy material handling;
Disadvantages:High equipment cost;Low efficiency

Hybrid Drying Systems

Hybrid drying systems are methods that use multiple drying techniques to achieve the desired dryness level without compromising product quality [27]. This technology can be used as an innovative and in term of energy efficiency alternative for drying foods.

Infrared-Assisted Hot Air Drying

IR is often used in conjunction with other drying techniques to overcome the limitations of the technology when used alone. The IR-assisted hot air drying technique achieves higher drying efficiency compared to the use of these techniques alone [28]. During IR-assisted hot air drying, high-speed air comes into direct contact with the material surface, forming a thin boundary layer on the material surface and thus increasing heat and mass transfer efficiency. This significantly reduces the drying time [29].

Vacuum-Assisted Microwave Drying

Studies on vacuum-assisted microwave drying have shown that this method produces more porous product structures with higher drying rates compared to conventional drying techniques. It has also been reported that samples obtained using this method have lower bulk density and minimal shrinkage. In drying processes using both microwaves and vacuum, samples with higher rehydration capacity compared to traditional methods, as well as lower water retention capacity, hardness, flexibility, stickiness, and chewability values have been obtained [30], [31], [32], [33].

IV. EFFECTS OF DRYING TECHNIQUES ON THE QUALITY CHARACTERISTICS OF RED PEPPER

Drying techniques play a significant role in the quality characteristics of dried peppers. These quality parameters include color, vitamin C level, aroma and flavor, rehydration capacity, and microbial safety. Red pepper is a sensitive product containing high pigment content, phenolic compounds, and aromatic compounds; therefore, even a minor change in drying conditions can significantly affect product quality.

Colour Parameters

Color can be the most effective quality indicator for red peppers. This is because color quality significantly determines the product's market price and consumer perception. Recent studies show that the most efficient methods for preserving the color of red peppers are hybrid methods such as microwave-assisted or infrared drying. Despite this advantage, maintaining color consistency between batches during large-scale production remains a challenge [34], [35].

Vitamin C Level

Vitamin C level is also an important factor in determining the drying method. One study found that hot air drying reduced the vitamin C content and antioxidant capacity of peppers [36]. On the other hand, freeze-drying and vacuum drying methods have been found to be the most effective methods for preserving vitamin C levels. However, disadvantages such as investment cost and energy consumption pose obstacles in industrial applications [3].

Aroma and Flavor Parameter

The choice of drying method has a significant effect on the aroma and flavor quality of peppers. The shade drying technique better preserves pigments, aroma compounds, and flavor, and minimizes the degradation of chemical components [37].

Rehydration Capacity

Rehydration capacity is an important indicator of physical quality. Freeze-drying is an important technique used for this purpose, but it has disadvantages such as high cost in addition to its advantages [38].

Microbial Load

Peppers are highly susceptible to microbial spoilage due to their high moisture content at harvest and their rapidly deteriorating structure. Even when stored under refrigerated conditions, their shelf life is limited [39]. IR drying is a promising technique in terms of its gentle and uniform heat distribution, preservation of color and nutrient content, and maintenance of microbial safety. However, the technique still has areas for improvement, such as the potential for surface burns due to high energy and limited penetration depth [40].

V.EFFECTS OF DIFFERENT DRYING METHODS ON QUALITY PARAMETERS

A comparision of the effects of drying methods on quality parameters of dried materials obtained from some studies in literature are illustrated in Table 1.

Table 1. Comparision of Different Drying Techniques

DRYİNG METHOD	DRYİNG METHOD	REFERENCE
Freeze-drying	• High polyphenol content • High total carotenoid content at low temperatures (40 °C) • High color retention (L* - brightness-high a*- redness-high b*- yellowness-low)	[41]
Vacuum drying	• Long drying time (40 °C) • High color retention (L*- brightness-high a*- redness-high b*- yellowness-low)	[41]
Infrared (IR) drying	• Short drying time • High phenolic compound content • High aroma compound content	[42]
Drying with far-infrared radiation	• Drying time (50 °C) 11 hours	[43]
IR-assisted hot air drying	• Short drying time (80 °C) 4 hours • Moderate color retention • Lower rehydration rate • Lower ascorbic acid content	[44]
Hot air drying	• Short drying time • Moderately high phenolic compound content • High color, texture, and appearance preservation (L*- brightness-high a* - redness - high)	[42]
	• Short drying time (80 °C) 5 hours • Moderate color retention • Low rehydration rate • Low ascorbic acid content	[44]
Pulsed vacuum drying	• Short drying time (80 °C) 6 hours • High degree of color retention • High rehydration rate • High ascorbic acid content	[44]

Sun drying	• High water retention capacity	[45]
	Long drying time (38 °C) approximately 2 days	[43]
Mixed-mode solar dryers	• Long drying time - approximately 48 hours • Moderate color retention • High total phenolic compound content	[46]
Microwave drying	• High ascorbic acid content • Low phenolic compound content	[45]
Intermittent microwave drying	• High color retention • Moderately high phenolic compound content • High aroma compound content	[42]
Vacuum-assisted microwave drying	• High color retention • High ascorbic acid level (L* - brightness-high a* - redness - high b* - yellowness - low) • High antioxidant activity value • High total phenolic compound content	[47]

In the freeze-drying method of hot red peppers, it was observed that the product obtained had a redder color than the raw material. A dried product with high color retention and high capsaicinoid retention was obtained at 40 °C. However, a decrease was observed as the temperature increased. The freeze-drying method also provides high polyphenol content in the products. In the vacuum drying method, the longest drying time was obtained at 40 °C. As in freeze-drying, the highest brightness and redness were achieved. When the temperature was increased from 40 °C to 60 °C, there was a 37% reduction in drying time for vacuum drying and a 32% reduction for freeze-drying [41].

When the effect of drying methods on fresh and dried powdered sweet peppers was investigated using infrared (IR), hot air, and intermittent microwave methods, lower color change ($p < 0.05$) was observed in the intermittent microwave method compared to the other two methods. This may be because microwave energy is directly absorbed by the water in the material and converted into heat through molecular motion, causing the temperature in the material to increase and thus providing a more stable drying process through effective redistribution of heat [42]. The compounds found in red pepper have been reported in previous studies [48]. An increase in the concentration of aroma compounds occurred after the drying process. Furthermore, the results obtained from the study showed that the total phenolic compound content was similar in intermittent microwave and hot air drying, while it was higher in infrared drying [42].

Another study on red pepper examined the effects of pulsed vacuum drying, infrared-assisted hot air drying, and hot air drying methods as drying techniques. It was observed that increasing the drying temperature reduced the drying time. At 80 °C, the shortest drying times were achieved with IR-assisted hot air drying (4 hours), hot air drying (5 hours), and pulsed vacuum drying (6 hours), respectively. Pulsed vacuum drying provided higher water retention capacity, brighter color, higher red pigment, and higher ascorbic acid content compared to the other two methods at the same drying temperature. Additionally, pulsed vacuum drying promoted the formation of a more porous structure, while hot air and IR-assisted hot air methods resulted in a less porous structure [44].

The effects of different drying techniques on Capsicum chinense (Chinese pepper) peppers were investigated. The results showed differences in antioxidant and nutritional properties depending on the drying method used and the ripeness level of the pepper. Microwave drying showed that red peppers dried using this method retained high levels of essential nutrients such as phenolic compounds, carotenoids, and ascorbic acid. Sun drying stood out for its high water retention capacity and ability to preserve flavonoid content [45].

In a study examining the quality characteristics of red pepper (Capsicum annuum) using different drying methods, sunlight, oven, and far-infrared rays (FIR) were used as methods. The shortest drying time was recorded as 11 hours in the FIR dryer at 50 °C, while it was 38 hours in sun drying and 46 hours in oven drying at 50 °C. The rehydration property was found to be almost similar (□ 39 hours) in sun drying and oven drying at 60 °C.

Compared to oven drying, the FIR method caused more volatile matter loss due to outdoor drying. This study showed that there was no significant difference between the far-infrared and oven dryer drying methods in terms of water content, VRS, ash level, and yield recovery [43].

The quality characteristics and drying kinetics of red pepper were investigated using various solar drying methods. As a result of the drying process carried out using direct solar dryers, indirect solar dryers, and mixed-mode solar dryers, a moderate change in color parameters was observed, and the average Δ L*, Δ a*, and Δ b* values were found to be -5.08, -23.71, and - 13.62, respectively. The highest phenolic compound content, 44.71%, was obtained in products dried using mixed-mode solar dryers. Compared to other drying methods, mixed-mode solar dryers showed lower total microbial counts, higher phenolic compound content, and antioxidant activity preservation properties [46].

As a result of vacuum-assisted microwave drying and drying red pepper in a hot air oven, the moisture content of red pepper decreased from 91.74% to below 10% in both processes. The drying time required to reach this level was determined to be 45-90 minutes. The highest antioxidant activity and total phenolic content were obtained with the vacuum-assisted microwave method. The highest vitamin C (ascorbic acid) level and high color retention were also observed with the vacuum-assisted microwave method [47].

V. CONCLUSION

According to the literature data reviewed in this study, the selected drying method was found to play an important role in the nutritional and sensory properties of red peppers. Although the traditional drying method, sun drying, is low-cost, it falls short of industrial standards due to long drying times, the potential risk of microbial contamination in the product, and seasonal dependence. Freeze-drying and vacuum-assisted microwave methods are preferred for preserving heat-sensitive bioactive compounds (ascorbic acid, total phenolic content, antioxidant capacity, etc.). When considering the color parameter, which is important for producers and especially consumers, pulsed vacuum drying, freeze drying, and vacuum-assisted microwave methods offer satisfactory results. In short, by using hybrid systems, both drying time can be shortened and energy efficiency increased, and the quality parameters of the product can be preserved at a higher level. Hybrid systems can be developed and promoted to eliminate the disadvantages of standalone systems.

REFERENCES

[1] T. STATISTICS, “Food and Agriculture Organization of the United Nations”, 2018.
[2] C. Li, Y. Wu, Q. Zhu, C. Xie, ve Y. Yan, “Alterations in physico-chemical properties, microstructure, sensory characteristics, and volatile compounds of red pepper (Capsicum annuum var. conoides) during various thermal drying durations”, Food Chem. X, c. 23, s. 101566, 2024.
[3] H. M. Elmatsani vd., “Global perspective on red chili drying: Insights from two decades of research (2004–2023)”, Front. Sustain. Food Syst., c. 8, s. 1456938, 2024.
[4] N. Sahar vd., “The impact of sun drying on the occurrence of aflatoxin in red chilies”, Journal of Basic & Applied Sciences, c. 13, ss. 632-637, 2017.
[5] M. Liu vd., “Effects of different hot-air drying methods on the dynamic changes in color, nutrient and aroma quality of three chili pepper (Capsicum annuum L.) varieties”, Food Chem. X, c. 22, s. 101262, 2024.
[6] H. Jang, M. Choi, ve K.-S. Jang, “Comprehensive phytochemical profiles and antioxidant activity of Korean local cultivars of red chili pepper (Capsicum annuum L.)”, Front. Plant Sci., c. 15, s. 1333035, 2024.
[7] Tarım ve Orman Bakanlığı (2023). Biber Ürün Bilgi Dosyası
[8] C. FAOSTAT, “Livestock Products, Food and Agricultural Organization of the United Nations, Statistics Division (FAOSTAT)”, 2023.
[9] https://www.harmantime.com.tr/uretimi-tuketimi-ihracati-artan-degerli-bir-sebze-kapya-biber/
[10] Türkiye İstatistik Kurumu (TÜİK). (2024). Bitkisel üretim istatistikleri, 2024. https://data.tuik.gov.tr/Bulten/Index?p=Crop-Production-Statistics-2024-53447
[11] ANONİM, Türkiye’nin dünyada lider olduğu ürünler. Gıda Tarım ve Hayvancılık Bakanlığı Bitkisel Üretim Genel Müdürlüğü Bugem Faaliyetleri. Ankara, 2014.
[12] H. Matsufuji, H. Nakamura, M. Chino, ve M. Takeda, “Antioxidant activity of capsanthin and the fatty acid esters in paprika (Capsicum annuum)”, J. Agric. Food Chem., c. 46, sy 9, ss. 3468-3472, 1998.
[13] M. Aslan ve N. Orhan, “Obezite tedavisine yardımcı olarak kullanılan doğal ürünler”, Mised, c. 23, sy 24, ss. 91-105, 2010.
[14] Cerit, İ. (2015). Kırmızı biberin (Capsicum annuum l.) fonksiyonel ve mikrobiyal özellikleri üzerine modifiye atmosferde paketlemenin etkisi (Master's thesis, Sakarya Universitesi (Turkey)).
[15] R. KASIM ve M. U. KASIM, “Renkli meyve ve sebzelerin bileşimi ve insan sağlığı açısından önemi”, CİLT 3, s. 31, 2019.
[16] K. Singletary, “Red pepper: overview of potential health benefits”, Nutr. Today, c. 46, sy 1, ss. 33-47, 2011.
[17] S. S. Pawar, N. V Bharude, S. S. Sonone, R. S. Deshmukh, A. K. Raut, ve A. R. Umarkar, “Chillies as food, spice and medicine: a perspective”, Int. J. Pharm. Biol. Sci., c. 1, sy 3, ss. 311-318, 2011.
[18] A. K. Maji ve P. Banerji, “Phytochemistry and gastrointestinal benefits of the medicinal spice, Capsicum annuum L.(Chilli): a review”, J. Complement. Integr. Med., c. 13, sy 2, ss. 97-122, 2016.
[19] W.-R. Kim vd., “Antioxidant activity of phenolics in leaves of three red pepper (Capsicum annuum) cultivars”, J. Agric. Food Chem., c. 62, sy 4, ss. 850-859, 2014.
[20] J.-H. Lim vd., “Supplementation with Aspergillus oryzae-fermented kochujang lowers serum cholesterol in subjects with hyperlipidemia”, Clinical Nutrition, c. 34, sy 3, ss. 383-387, 2015.
[21] M. Mueller, V. Beck, ve A. Jungbauer, “PPARα activation by culinary herbs and spices”, Planta Med., c. 77, sy 05, ss. 497-504, 2011.

[22] P. Mohapatra, A. Ray, S. Jena, S. Nayak, ve S. Mohanty, “Influence of various drying methods on physicochemical characteristics, antioxidant activity, and bioactive compounds in Centella asiatica L. leaves: a comparative study”, Biotechnologia, c. 103, sy 3, ss. 235-247, 2022.

[23] J.-K. Yan, L.-X. Wu, Z.-R. Qiao, W.-D. Cai, ve H. Ma, “Effect of different drying methods on the product quality and bioactive polysaccharides of bitter gourd (Momordica charantia L.) slices”, Food Chem., c. 271, ss. 588-596, 2019.

[24] A. E. Drouzas, E. Tsami, ve G. D. Saravacos, “Microwave/vacuum drying of model fruit gels”, J. Food Eng., c. 39, sy 2, ss. 117-122, 1999.

[25] D. Huang, P. Yang, X. Tang, L. Luo, ve B. Sunden, “Application of infrared radiation in the drying of food products”, Trends Food Sci. Technol., c. 110, ss. 765-777, 2021.

[26] A. Menon, V. Stojceska, ve S. A. Tassou, “A systematic review on the recent advances of the energy efficiency improvements in non-conventional food drying technologies”, Trends Food Sci. Technol., c. 100, ss. 67-76, 2020.

[27] S. K. Chou ve K. J. Chua, “New hybrid drying technologies for heat sensitive foodstuffs”, Trends Food Sci. Technol., c. 12, sy 10, ss. 359-369, 2001.

[28] B. Li, J. Lin, Z. Zheng, H. Duan, D. Li, ve M. Wu, “Effects of different drying methods on drying kinetics and physicochemical properties of Chrysanthemum morifolium Ramat”, International Journal of Agricultural and Biological Engineering, c. 12, sy 3, ss. 187-193, 2019.

[29] E. J. Bassey, J.-H. Cheng, ve D.-W. Sun, “Novel nonthermal and thermal pretreatments for enhancing drying performance and improving quality of fruits and vegetables”, Trends Food Sci. Technol., c. 112, ss. 137-148, 2021.

[30] Q. Guo, D.-W. Sun, J.-H. Cheng, ve Z. Han, “Microwave processing techniques and their recent applications in the food industry”, Trends Food Sci. Technol., c. 67, ss. 236-247, 2017.

[31] A. Aydogdu, G. Sumnu, ve S. Sahin, “Effects of microwave-infrared combination drying on quality of eggplants”, Food Bioproc. Tech., c. 8, sy 6, ss. 1198-1210, 2015.

[32] E. Horuz, H. Bozkurt, H. Karataş, ve M. Maskan, “Drying kinetics of apricot halves in a microwave-hot air hybrid oven”, Heat and Mass transfer, c. 53, sy 6, ss. 2117-2127, 2017.

[33] A. Nawirska-Olszańska, B. Stępień, ve A. Biesiada, “Effectiveness of the fountain-microwave drying method in some selected pumpkin cultivars”, LWT, c. 77, ss. 276-281, 2017.

[34] I. Zahoor, T. A. Ganaie, ve S. A. Wani, “Effect of microwave assisted convective drying on physical properties, bioactive compounds, antioxidant potential and storage stability of red bell pepper”, Food Chemistry Advances, c. 3, s. 100440, 2023.

[35] M. Lučić vd., “Influence of ultrasonic and chemical pretreatments on quality attributes of dried pepper (Capsicum annuum)”, Foods, c. 12, sy 13, s. 2468, 2023.

[36] G. Speranza, R. Lo Scalzo, C. F. Morelli, M. Rabuffetti, ve G. Bianchi, “Influence of drying techniques and growing location on the chemical composition of sweet pepper (Capsicum annuum L., var. Senise)”, J. Food Biochem., c. 43, sy 11, s. e13031, 2019.

[37] H. Pinar, N. Çetin, B. Ciftci, K. Karaman, ve M. Kaplan, “Biochemical composition, drying kinetics and chromatic parameters of red pepper as affected by cultivars and drying methods”, Journal of Food Composition and Analysis, c. 102, s. 103976, 2021.

[38] T. Fauster, M. Giancaterino, P. Pittia, ve H. Jaeger, “Effect of pulsed electric field pretreatment on shrinkage, rehydration capacity and texture of freeze-dried plant materials”, Lwt, c. 121, s. 108937, 2020.

[39] T. Hernández-Pérez, M. del R. Gómez-García, M. E. Valverde, ve O. Paredes-López, “Capsicum annuum (hot pepper): An ancient Latin-American crop with outstanding bioactive compounds and nutraceutical potential. A review”, Compr. Rev. Food Sci. Food Saf., c. 19, sy 6, ss. 2972-2993, 2020.

[40] C. K. Anumudu, H. Onyeaka, C. T. Ekwueme, A. Hart, F. Isaac-Bamgboye, ve T. Miri, “Advances in the application of infrared in food processing for improved food quality and microbial inactivation”, Foods, c. 13, sy 24, s. 4001, 2024.

[41] A. Krzykowski vd., “Drying of red chili pepper (Capsicum annuum L.): Process kinetics, color changes, carotenoid content and phenolic profile”, Molecules, c. 29, sy 21, s. 5164, 2024.

[42] G. Guclu vd., “Impact of production and drying methods on the volatile and phenolic characteristics of fresh and powdered sweet red peppers”, Food Chem., c. 338, s. 128129, 2021.

[43] R. Rachmat1a, H. Harris, A. Maruf, ve A. Ginantaka, “Quality Evaluation of Dried Red Chili (Capsicum annuum L) with Convection and Radiation Drying Methods Evaluasi Mutu Cabai Merah Kering (Capsicum annuum L) dengan Metode Pengeringan Konveksi dan Radiasi”.

[44] D. L. Deng LiZhen vd., “Red pepper (Capsicum annuum L.) drying: effects of different drying methods on drying kinetics, physicochemical properties, antioxidant capacity, and microstructure.”, 2018.

[45] M. O. Faruk, R. M. Galib, M. A. I. Bulbul, ve M. Alam, “Optimizing Drying Techniques for Capsicum chinense: Impacts on Physicochemical, Functional, and Bioactive Properties”, Food Chemistry Advances, s. 101126, 2025.

[46] H. Chaji, P. Sharayei, M. Hedayatizadeh, Y. Sabeghi, ve D. Gandomzadeh, “Drying Kinetics and Quality Attributes of Solar-Dried Red Peppers: A Comparative Study with Traditional and Industrial Methods”, J. Food Process. Preserv., c. 2024, sy 1, s. 7987269, 2024.

[47] C. Baltacıoğlu ve D. Boz, “Kırmızıbiberin vakum destekli mikrodalga tekniği ile kurutulması”, Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, c. 14, sy 1, ss. 18-26, 2025.

[48] A. Korkmaz, A. A. Hayaloglu, ve A. F. Atasoy, “Evaluation of the volatile compounds of fresh ripened Capsicum annuum and its spice pepper (dried red pepper flakes and isot)”, Lwt, c. 84, ss. 842-850, 2017.