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# A Comprehensive Analysis of Apricot Drying Methods via Multi-Criteria Decision Making Techniques

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## ABSTRACT

Food and food safety have been among the most important issues for people throughout history. Societies have always tried to be self-sufficient in food and have avoided becoming dependent on foreign sources. However, the fact that most foods are seasonal and the increasing population's food consumption have revealed the need to preserve foodstuffs for a long time. The old and well-known method used today for extending shelf life is the drying process. The drying process is preferred over other preservation methods for reasons such as being more economical, easier to transport, having a longer shelf life, more concentrated nutritional value, and containing fewer additives. This ensures that dried foods are of higher quality in terms of physical, chemical, microbial properties, and nutritional values compared to other packaged foods. While the drying process was traditionally done over a long period, technological advancements have led to the production of higher quality and more valuable commercial products in a shorter time. In this study, traditional and technological methods used in drying apricots were compared according to the parameters determined by experts in the field. Since multiple parameters are effective in the comparison, Multi-Criteria Decision Making (MCDM) techniques were used. The optimum apricot drying method was determined by combining the results obtained from different MCDM techniques with the Borda rule.

## 1 | Introduction

The rapidly increasing nutritional needs of the world population highlight the importance of longer-term preservation and storage of foods. Agricultural products start to rot or deteriorate after a certain period once they are harvested. While this period is longer for dry foods, it is shorter for fresh fruits and vegetables. Foods that are not stored under suitable conditions lose their characteristics such as flavor, color, taste, and nutritional value, and also cause an economic loss because they spoil and rot. Various methods have been used in the past to preserve the nutritional values and quality of products for a long time. Preserving foods by drying is the most common and oldest preservation method which is cost-effective and allows easy storage

and transportation of foods, intensification of their nutritional value, extension of storage periods, and reduction of storage costs. Also, it requires less labor and equipment than many other methods.

Drying reduces the moisture level in the food, preventing the development of various microorganisms. Dried foods can be consumed directly, such as dried fruits, or can be used as raw materials for other packaged food products. Although the main purpose of the drying process is to improve the storage conditions of products and extend their shelf life, it also contributes to the reduction of costs such as production, packaging, transportation, and storage (Santos and Silva 2009). These costs for dried foods are less than those for canned and

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## Summary

- The food industry, aiming to meet the rapidly increasing food needs of societies, offers seasonal products to consumers by preserving them through various methods.
- One of the methods is drying. Many methods are employed in the food drying industry, each with its own advantages and disadvantages.
- Additionally, each method has different effects on the parameters of dried foods.
- Considering all these factors together, a complex problem arises where multiple options and parameters are influential.
- The aim of this study is to determine the most optimal drying method, addressing this complexity and uncertainty, and to provide decision support to producers.

frozen foods (Alwazeer 2018). Drying foods is a suitable alternative for post-harvest management, especially in countries where low-temperature storage and transportation opportunities are limited. The moisture content of fresh fruits and vegetables is generally high, and if they are not dried in time, they can mold and spoil, negatively affecting product quality (Zambrano et al. 2019).

In particular, the intensive production of freshly consumed fruits such as apricots, figs, and grapes, and their intensive consumption as dried food, make these products commercial commodities. Apricots, which are produced and consumed in large quantities worldwide, are rich in minerals such as vitamin A, iron, calcium, phosphorus, and copper (Dağ, Tarakçı, and Demirkol 2016). However, apricots are perishable fruits and are sensitive to the growth of microorganisms, causing them to spoil quickly. For this reason, measures must be taken to increase the shelf life and quality of the products (De Corato 2020). When economic losses are added to the quality and nutritional value loss caused by inappropriate food preservation methods, a major food safety threat emerges. Therefore, the selection of the most efficient preservation method is becoming increasingly important every day (Ratti 2001).

Many new technologies have been invented in addition to traditional methods to better preserve the color, flavor, textural and structural properties, and nutritional value of foods, and to make them ready for consumption quickly. New drying methods, developed in parallel with technological innovations, are frequently applied in apricot drying. However, each method has its own advantages and disadvantages. Additionally, there are many factors affecting the selection of the drying method. Experts discuss the results of these methods, either alone or in combination, and conduct hundreds of studies.

In the literature, several studies have been conducted on various aspects of drying processes, including the comparison of different apricot drying methods (Kaplan and Levent 2019), modeling approaches used in drying (Kilic et al. 2024), tomato drying methods (Şahin 2010), the effect of different drying methods on the phenolic properties of Malatya apricot (Kaplan

et al. 2019), the design of a solar food dryer (Memur 2022), the effect of different drying methods on drying characteristics (Yang et al. 2024), optimization of dried apple chips production (Kenzhekhanova, Mukhametov, and Mamayeva 2024), the effect of apricot drying methods on the phenolic properties of the product (Dağ, Tarakçı, and Demirkol 2016), mathematical modeling of apricot drying with the microwave method (İzli 2016), the effect of apricot drying methods on the chemical and physical properties of the product (Coşkun et al. 2013), the effect of the drying process on product properties (Garcia-Martinez et al. 2013), the effect of microwave and hot air drying methods on product color (Albanese et al. 2013), the use of infrared radiation in pre-drying processes (Zare, Azadbakht, and Naseri 2024), the effect of drying methods on the properties of apricot pestil (Suna et al. 2014), the comparison of textural and quality properties of dried apricots (Horuz et al. 2018), and the effect of apricot size and drying method on product chemical properties (Karabulut et al. 2018). Some different new heating techniques (Kilic and Baskaya 2017; Kilic and Ozcan 2019) were also used for industrial application as drying fruits.

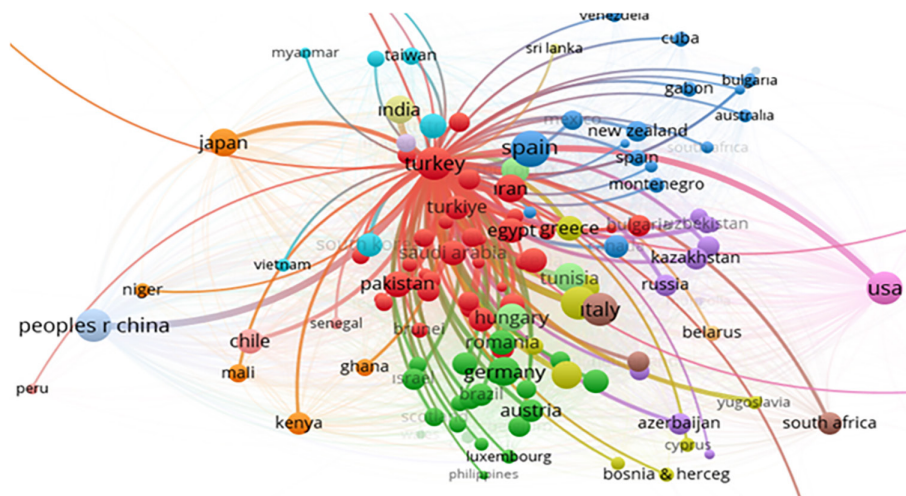
While previous studies have compared various drying methods or examined the effects of different properties of dried foods, no research has been found that simultaneously compares apricot drying methods across multiple parameters to identify the optimal approach. This study aims to fill that gap, providing a comprehensive analysis of apricot drying methods.

Multi-Criteria Decision Making (MCDM) techniques, which allow the integrated evaluation of these studies, are widely used in decision problems where more than one parameter is effective. In the literature, studies have been carried out on the comparison of packaged drinking water brands with MCDM techniques (Abdulvahitoğlu 2024), the evaluation of the sustainability of rural agricultural activities (Haloui et al. 2024), the optimization of pineapple drying (Chauhan et al. 2021), the evaluation of factors causing vegetable and fruit losses and waste in the supply chain (Haider and Choubey 2024), the prioritization of potential sun drying problems (Dwivedi et al. 2023), and the development of a model for sweet potato breeding studies (Xiang et al. 2023). Additionally, a literature search in Web of Science analyzed with the VOSviewer program shows that there are hundreds of different apricot-themed studies, as illustrated in Figure 1. However, there are currently no studies evaluating the methods used in apricot drying based on multiple criteria to determine the optimal drying method.

Therefore, the most commonly used apricot drying techniques were investigated, their effects on dried apricot parameters were explained, and the opinions of experts working as academicians in food engineering were sought. The main purpose of this study is to determine the optimum apricot drying technique, taking into account new technological developments in food drying systems.

The stages of this study, which considered nutritional value, production speed, color, flavor, shelf life, and customer expectations in the apricot drying process, are shown in Figure 2.





**FIGURE 3** | Countries where apricot themed study was conducted.

et al. 2021). The antioxidant activity of apricots helps with a range of medical disorders by strengthening the body's defenses against free radicals and lowering their oxidative impact (Karataş and Sengül 2020; Hamid et al. 2010). Atherosclerosis, coronary heart disease, hepatic steatosis, oxidative intestinal damage, tumor growth, and chronic gastritis are some of these medical disorders. Apricots also have soluble dietary fibers that lower LDL cholesterol (Fatima et al. 2018), which is beneficial for the liver and heart.

Various methods are employed in apricot processing, including sun drying, hot drying, vacuum drying, infrared drying, microwave drying, and freeze drying (Yang et al. 2024; Günaydın, Sağlam, and ve Çetin 2022). Each apricot drying system has distinct advantages and disadvantages. Traditional methods, while widely used, can lead to excessive loss of nutritional value and pose risks such as toxic gases and microbial contamination (Megias-Perez et al. 2014; Polatçı, Taşova, and Saraçoğlu 2020). Technological drying systems offer improved quality through controlled environments and efficient heat utilization (Kocayığıt 2010). Optimal selection of drying methods and modeling of the drying process is crucial to minimize adverse effects and maximize benefits (Sablani 2006; Karatas and Kamışlı 2007). The commonly used drying methods are explained below.

**2.1.1.1 | Sun Drying.** Sun drying is the most common and widely used traditional and natural method for drying apricots. However, its effectiveness can vary depending on solar heat and light availability, which may not be consistent across different times and locations. Compared to artificial methods, sun drying tends to be slower, less hygienic, and less uniform in process speed. This method relies on solar heat and light to remove water and moisture content from apricots. The variability in drying conditions from day to day can hinder the efficient and sustainable use of solar energy (Cankurtaran 2018). Sun drying involves labor-intensive processes, extended drying times, and vulnerability to contaminants such as dust, soil, gases, rain, insects, and other organisms, all of which can negatively affect product quality. Additionally, prolonged exposure to solar heat and light may cause vitamin loss and color degradation in dried apricots (Karabulut et al. 2018). Among the disadvantages of this method are its slow pace and reliance on weather conditions (Inyang, Oboh, and Etuk 2017).

**2.1.1.2 | Hot Drying.** In hot drying, air heated from an external energy source is directed onto the product in its environment. Once dried, the product is cooled and then stored (Şahin 2010). This method offers faster processing compared to sun drying and effectively inhibits microbiological processes, thereby minimizing negative impacts on product quality (Karabulut et al. 2018). Comparatively poor quality control due to the process's low energy efficiency and the quick drying of food when it is near a heat source (Inyang, Oboh, and Etuk 2017).

**2.1.1.3 | Vacuum Drying.** Vacuum drying is particularly suitable for fruits requiring extended drying times, significantly reducing drying duration. It facilitates easier removal of water and moisture from food at lower temperatures compared to atmospheric conditions. By reducing air reactions, vacuum drying preserves color, texture, and aroma more effectively. Developed to enhance the quality of foods vulnerable to heat damage during drying, it maintains superior product attributes (Şahin 2010). This method operates under low pressure and requires a substantial amount of energy, which are considered its primary disadvantages (Inyang, Oboh, and Etuk 2017).

**2.1.1.4 | Microwave Drying.** Microwave drying complements hot and vacuum drying methods, enhancing efficiency and quality by converting electromagnetic energy into heat energy. It accelerates the drying of high-moisture products at the outset, lowering process costs and increasing speed and efficiency. Its key advantage lies in uniform heat distribution throughout the food, achieved through high conductivity (Maskan 2000; Göğüş, Özel, and Lewis 2007). Compared to other methods, microwave drying achieves the required heat levels rapidly, boosting production speed (Fратиanni et al. 2013).

**2.1.1.5 | Freeze Drying.** Freeze drying preserves product freshness exceptionally well by removing water and moisture via sublimation. This method effectively prevents microbial and spoilage issues, ensuring the highest quality standards. However, its high-cost limits widespread use despite minimal flavor and color changes compared to sun, heat, and vacuum drying methods (Şahin 2010; Sablani et al. 2007).

**2.1.1.6 | Infrared Drying.** Infrared drying involves the use of specialized drying rooms where the drying process occurs under controlled conditions. The temperature of the heating plate and the radiation power are set to specific levels (Yang et al. 2024). Higher radiation intensity accelerates the drying process. This method is favored due to its ability to evenly and effectively penetrate the product with radiation, as well as its lower installation and operating costs compared to other drying methods. Moreover, it is not influenced by external meteorological conditions (Aktaş et al. 2013).

## 2.1.2 | Parameters Affecting Apricot Drying Methods

When studying drying methods for food and specifically apricots, experts evaluate them based on several critical parameters:

**2.1.2.1 | Aroma.** The aroma of food is formed by both permanent and volatile components, where volatile components contribute significantly to the smell. Drying apricots, known for their rich aroma, can lead to the loss of volatile components, negatively impacting product quality (Kaplan and ve Levent 2019).

**2.1.2.2 | Nutritional Value.** The nutritional value of food includes proteins, fats, carbohydrates, vitamins, and minerals, which are susceptible to external influences. Proper storage and preservation methods are crucial for maintaining nutritional quality. Dried foods generally retain higher nutritional value and fiber content compared to products preserved using other methods (Kutlu, İşçi, and Demirkol 2015; Kakşi 2021).

**2.1.2.3 | Color Protection.** The appearance of food plays a vital role in consumer preferences. Methods like hot drying and microwave drying may cause more discolouration compared to other drying methods, affecting consumer perception (İncedayı et al. 2016; Alwazeer 2018).

**2.1.2.4 | Texture and Structural Properties.** Texture refers to the tactile sensations experienced while consuming food, which can influence its quality and consumer satisfaction. Changes in texture due to storage methods and duration are critical factors affecting consumer acceptance and repurchase decisions (ABP 2024).

**2.1.2.5 | Production Speed.** Various factors including food chemistry, size, shape, thickness, air temperature, humidity, atmospheric pressure, and drying method significantly impact drying time. Faster drying processes save time, labour,

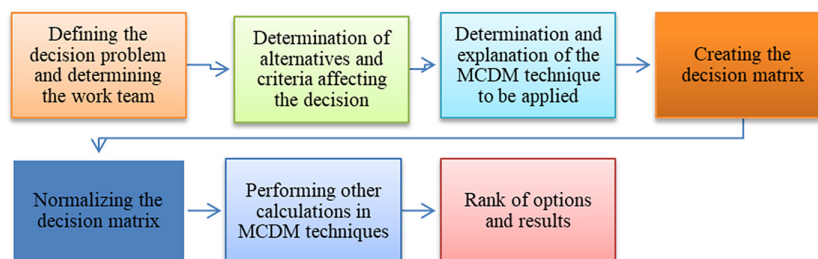
and costs associated with production (Sarsılmaz 1998; Kutlu, İşçi, and Demirkol 2015).

**2.1.2.6 | Taste.** Taste is the sensory perception of food in the mouth, crucial for consumer acceptance. Regardless of nutritional content, if consumers dislike the taste of a product, they are less likely to repurchase it (Sayaslan and Akpınar 2003).

**2.1.2.7 | Shelf Life.** With increasing demand to consume seasonal products year-round, extending shelf life has become essential. Different drying methods and additives are employed to prolong shelf life while maintaining product quality. Products with fewer additives and longer shelf lives are preferred for their higher quality (Şahin 2010).

## 2.2 | Multi-Criteria Decision Making (MCDM) Techniques

MCDM techniques, applied across various domains, enable decision-makers to evaluate numerous factors comprehensively. These techniques are particularly useful for decision problems involving ranking or weighting criteria (Abdulvahitoğlu, Abdulvahitoğlu, and Kılıç 2022). The literature encompasses approximately 200 MCDM techniques. These methods are employed for various purposes, such as weighting criteria, ranking options, or both. In this study, the Entropy technique is employed for weighting, while the TOPSIS, COPRAS, MAUT, MOORA, MOOSRA, MAIRCA, and MABAC techniques are used for ranking. All of the preferred methods are specifically designed for ranking. Since the process undertaken here focuses on ranking options, only those methods frequently used in the literature for this purpose were chosen. Another reason for their selection is that they are simple, clear, and easy to apply for researchers while remaining straightforward and comprehensible for readers. Furthermore, the mathematical formulas on which these methods are based are widely accepted by experts. Additionally, all of these methods account for both the best and worst solutions or in other words, they incorporate both benefit-oriented and cost-oriented criteria in separate calculations. Moreover, a combination of both older and more recent methods has been used, including frequently employed Multi-Criteria Decision-Making (MCDM) methods from the past, in order to explore whether using both old and new methods together results in any differences in outcomes. These results are integrated using the Borda rule. MCDM techniques typically involve a series of steps, illustrated in Figure 4, to conduct operations effectively.



**FIGURE 4** | Multi-criteria decision making process.

### 2.2.1 | Entropy Technique

In decision problems involving multiple factors, determining the weights of these factors arises, making decision-making even more complex. Since the weights of the factors significantly affect the outcome of the decision-making process, it is important to determine them objectively (Petrovic, Zivanovic, and Mihajlovic 2023). Entropy is a measure of the uncertainty associated with a random variable. The Entropy technique, developed based on Shannon's theory (Shannon 1948), makes weightings based on irregularities in the criteria (Wang and Lee 2009). In the literature, it is evident that the Entropy technique is widely used to weight the factors affecting the decision. In decision-making, the weights of the parameters used to evaluate the options reflect the relative importance of these parameters. Subjective opinions, prejudices, or incomplete information complicate and make decision-making processes more difficult. In this context, the Entropy technique is frequently preferred as a sensitive technique for determining the weights of the criteria affecting the decision (Özbek and Oğuz 2024).

The weighting of the parameters is done by applying Equations (1)–(6) below using the Entropy technique (Özçalın and Bircan 2023).

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \dots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \quad (1)$$

$$r_{ij} = \frac{x_{ij}}{\sum_i x_{ij}} \quad (2)$$

$$k = (\ln(n))^{-1} \quad (3)$$

$$e_j = -k \sum_{i=1}^n r_{ij} * \ln(r_{ij}) \quad (i = 1 \dots n, j = 1 \dots m) \quad (4)$$

$$d_j = 1 - e_j \quad (j = 1 \dots m) \quad (5)$$

$$w_j = \frac{1 - e_j}{\sum_{i=1}^n (1 - e_j)} \quad (6)$$

The values obtained from the calculations represent the weights of the criteria.

### 2.2.2 | Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Technique

In decision problems, it was developed by Hwang and Yoon to rank the existing alternatives according to the determined parameters. In this method, the parameters are evaluated according to their positive and negative distances from the ideal solution, and the optimum result is found (Hwang and Yoon 1981). It is one of the MCDM techniques that helps decision-makers evaluate alternatives according to the determined parameters in many different areas of life (Chen and ve Hwang 1992). This

technique is based on determining the option that is closest to the ideal solution with the best values. It also considers the option that is farthest from the undesirable negative solution or results. TOPSIS is frequently used in academic studies as it provides convenience to the decision-maker in real problems. In the TOPSIS method, the options are ranked by applying Equations (7)–(13) below (Abdulvahitoğlu, Abdulvahitoğlu, and Kılıç 2022; Abdulvahitoglu and Kılıç 2022).

$$D_{ij} = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \vdots & & & \vdots \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix} \quad (7)$$

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^m a_{kj}^2}} \quad (8)$$

$$S^* = \left\{ \left( \max_i v_{ij} | j \in J \right), \left( \min_i v_{ij} | j \in J' \right) \right\} \quad (9)$$

$$S^- = \left\{ \left( \min_i v_{ij} | j \in J \right), \left( \max_i v_{ij} | j \in J' \right) \right\} \quad (10)$$

$$S_i^* = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^*)^2} \quad (11)$$

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (12)$$

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (13)$$

The  $C_i^*$  values obtained from the calculations are ranked in descending order to determine the order of the options.

### 2.2.3 | The Complex Proportional Assessment (COPRAS) Technique

The COPRAS technique, developed by Zavadskas and Kaklauskas in 1996, is used to evaluate alternatives by considering the benefit and cost objectives of the factors belonging to the problem. The biggest advantage of the technique is that it can compare the options and express proportionally how much better or worse they are compared to other options (Özbek 2017). It is easier to apply due to the use of shorter processes and simpler formulas compared to other MCDM methods during calculation. The COPRAS technique is applied using Equations (14)–(20) given below (Hezer, Gelmez, and ve Özceylan, E. 2021; Hezam et al. 2023).

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (14)$$

$$X_{ij}^* = \frac{x_{ij}}{\sum_{i=1}^m X_{ij}} \quad (15)$$

$$r_{ij} = x_{ij}^* w_j \quad (16)$$

$$S_i^+ = \sum_{j=1}^k r_{ij} \quad (17)$$

$$S_i^- = \sum_{j=k+1}^k r_{ij} \quad (18)$$

$$Q_i = S_i^+ + \frac{\sum_{i=1}^m S_i^-}{S_i^- \sum_{i=1}^m \left(\frac{1}{S_i^-}\right)} \quad (19)$$

$$P_i = \left(\frac{Q_i}{Q_{max}}\right) * 100 \quad (20)$$

The options are ranked by sorting the  $P_i$  values obtained from the calculations from largest to smallest.

### 2.2.4 | Multi-Attribute Utility Theory (MAUT) Technique

MAUT is one of the most useful techniques used to solve intuitive connection and decision-making problems. It allows the decision-maker to evaluate all factors without making any distinction between qualitative and quantitative aspects (Ishizaka and Nemery 2012). Each alternative is assessed based on outputs evaluated in different dimensions. The MAUT technique facilitates comparison by aggregating values from these different dimensions into a single metric. The technique is applied using Equations (21)–(25) provided below (Zietsman, Rilett, and Kim 2006; Öztel 2016).

$$X = \begin{bmatrix} x_{11}, x_{12} & \cdots & x_{1n} \\ x_{21}, x_{22} & \ddots & x_{2n} \\ \cdots & \cdots & \cdots \\ x_{m1}, x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (21)$$

$$x_j(a_i) = \frac{x_i(a_i) - \min(x)}{\max(x_i) - \min(x_i)} \quad (22)$$

$$x_j(a_i) = 1 + \frac{x_j - x_i(a_i)}{\max(x_i) - \min(x_i)} \quad (23)$$

$$r_{ij} = \frac{e^{(x_{ij})^2}}{1,71} \quad (24)$$

$$X(a_i) = \sum_{j=1}^q x_j(a_i) \cdot w_j \quad (25)$$

The options are ranked by sorting the  $X(a_i)$  values obtained from the calculations from largest to smallest.

### 2.2.5 | Multi-Objective Optimization Based on Ratio Analysis (MOORA) Technique

One advantage of the technique is its capability to accommodate both types of criteria together, whether they are aimed to be maximized or minimized (Çakır and Bilge 2019). The technique is applied using Equations (26)–(29) provided below (Hafezalkotob, Liao, and Herrera 2019).

$$X = \begin{bmatrix} x_{11} x_{12} & \cdots & x_{1n} \\ x_{21} x_{22} & \ddots & x_{2n} \\ \cdots & \cdots & \cdots \\ x_{m1} x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (26)$$

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (27)$$

$$v_{ij} = w_j * x_{ij}^* \quad (28)$$

$$y_i^* = \sum_{j=1}^g v_{ij} - \sum_{j=g+1}^n v_{ij} \quad (29)$$

$y_i^*$  represents the normalized evaluation of the  $i$ th alternative based on all features. The MOORA-Ratio approach ranks the  $y_i^*$  values obtained from the calculations.

### 2.2.6 | Multi-Attributive Ideal Real Comparative Analysis (MAIRCA) Technique

MAIRCA, introduced to the MCDM literature by Gigovic et al., is a technique that focuses on identifying discrepancies between ideal and actual ratings. By summing these discrepancies across each criterion, the total gap for decision alternatives is calculated. At the end of the application process, the alternative that closely aligns with the ideal ratings across most criteria, or in other words, has the smallest total gap value, is determined as the best alternative (Gigovic et al. 2016; Rani, Chen, and Mishra 2023). The MAIRCA technique is applied using Equations (30)–(40) provided below (Pamucar, Tarle, and Parezanovic 2018):

$$X^* = \begin{bmatrix} x_{11}^* & \cdots & x_{1p}^* \\ \vdots & \ddots & \vdots \\ x_{m1}^* & \cdots & x_{mn}^* \end{bmatrix} (i = 1, \dots, m \text{ and } j = 1, \dots, n) \quad (30)$$

$$n_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \quad (31)$$

$$n_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \quad (32)$$

$$N = \begin{bmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{m1} & \cdots & n_{mn} \end{bmatrix} \quad (33)$$

$$P_i = P_{i+1} = \dots = P_m = 1/m \quad (34)$$

$$t_{ij} = P_i * w_{ij} \quad (35)$$

$$r_{ij} = t_{ij} * n_{ij} \quad (36)$$

$$R = \begin{bmatrix} t_{11}n_{11} & \dots & t_{1n}n_{1n} \\ \vdots & \ddots & \vdots \\ t_{m1}n_{m1} & \dots & t_{mn}n_{mn} \end{bmatrix} \quad (37)$$

$$G = T - R \quad (38)$$

$$G = \begin{bmatrix} t_{11} - r_{11} & \dots & t_{1n} - r_{1n} \\ \vdots & \ddots & \vdots \\ t_{m1} - r_{m1} & \dots & t_{mn} - r_{mn} \end{bmatrix} \quad (39)$$

$$Q_i = \sum_j^n g_{ij} \quad (40)$$

The options are ranked by sorting the  $Q_i$  values obtained from the calculations from largest to smallest.

### 2.2.7 | Multi-Objective Optimization Based on Simple Ratio Analysis (MOOSRA) Technique

The MOOSRA technique, developed by Das et al. in 2012, is preferred due to its short calculation time, minimal mathematical operations, high reliability, and simple applicability. Steps 1 and 2 of the technique mirror those of the MOORA technique, differing in the 3rd step where the totals of benefit criteria and cost criteria are proportioned (Demircioğlu and Çoskun 2018). The MOOSRA technique is implemented using the Equations (41)–(44) provided below (Das, Sarkar, and Ray 2013):

$$X^* = \begin{bmatrix} x_{11}^* & \dots & x_{1p}^* \\ \vdots & \ddots & \vdots \\ x_{m1}^* & \dots & x_{mn}^* \end{bmatrix} \quad (i = 1, \dots, m \text{ and } j = 1, \dots, n) \quad (41)$$

$$x_{ij}^* = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}^2} \quad (42)$$

$$a_{ij} = x_{ij}^* \cdot w_j \quad (43)$$

$$Y_i = \frac{\sum_j^g x_{ij}^* \cdot w_j}{\sum_{j'=g+1}^n x_{ij'}^* \cdot w_{j'}} \quad (44)$$

$j = 1, 2, \dots, g$  for beneficial,  $j' = g + 1, g + 2, \dots, n$  for cost.

The options are ranked by sorting the  $Y_i$  values obtained from the calculations from largest to smallest.

### 2.2.8 | Multi-Attributive Border Approximation Area Comparison (MABAC) Technique

The MABAC technique, first applied by Pamucar and Cirovic in 2015, evaluates decision alternatives by considering their distances to the boundary proximity area of criterion functions.

This technique is employed in multi-criteria decision-making (MCDM) to select the best option from various criteria, applicable in both institutional and individual decision-making processes. The MABAC technique is implemented using the Equations (45)–(50) provided below (Pamucar and Cirovic 2015; Stojanovic and Puska 2021).

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (45)$$

$$r_{ij} = \frac{X_{ij} - X_j^{min}}{X_j^{max} - X_j^{min}} \quad (46)$$

$$r_{ij} = \frac{X_{ij} - X_j^{max}}{X_j^{min} - X_j^{max}} \quad (47)$$

$$V_{ij} = W_j * (1 + r_{ij}) \quad (48)$$

$$g_i = \left( \prod_{i=1}^m V_{ij} \right)^{\frac{1}{m}} \quad (49)$$

$$G = [g_i]_{1*n} \quad (50)$$

$$Q = (v_i - G) = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \dots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \dots & v_{2n} - g_n \\ \dots & \dots & \dots & \dots \\ v_{m1} - g_1 & v_{m2} - g_2 & \dots & v_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & \dots & q_{1m} \\ q_{21} & q_{22} & \dots & q_{2m} \\ \vdots & \ddots & \ddots & \vdots \\ q_{n1} & q_{n2} & \dots & q_{nm} \end{bmatrix} \quad (51)$$

$$A_i \in \begin{cases} G^+ & \text{if } q_{ij} > 0 \\ G & \text{if } q_{ij} = 0 \\ G^- & \text{if } q_{ij} < 0 \end{cases} \quad (52)$$

$$S_i = \sum_{j=1}^n q_{ij} \quad (53)$$

The options are ranked by sorting the  $S_i$  values obtained from the calculations from largest to smallest.

### 2.2.9 | Borda Rule

The Borda rule, developed by Borda in 1784, is a voting method in social choice theory. It combines rankings obtained from multiple methods to derive a single ranking (Akyüz and Aka 2017; Wu et al. 2011). According to the Borda rule, the most preferred alternative receives  $(n - 1)$  points, the least preferred receives 0 points, and the remaining alternatives receive points incrementally. These operations are governed by Equation (54) (Hacıfettahoğlu and Pereçin 2020).

In this study, each MCDM technique's results will be scored using the Borda rule. The Borda scores will then be aggregated,

TABLE 1 | Apricot drying methods and parameters.

Direction of parameters	Aroma preservation		Nutritional values		Color protection		Texture and structural features		Flavor		Shelf life		Production speed	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Sun drying	1	1	1	1	2	3	3	3	3	3	3	3	3	3
Hot drying	2	2	2	2	3	3	3	3	3	3	3	3	3	3
Microwave drying	5	4	4	5	5	5	5	4	4	4	4	5	5	5
Freeze drying	5	5	5	5	5	4	4	4	4	4	4	5	3	3
Vacuum drying	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Infrared drying	3	3	3	3	4	3	3	3	3	3	3	4	4	4

total scores calculated for each alternative, and final rankings determined.

$$B_i = \sum_{k=1}^r m - a_{ik} \quad (54)$$

### 3 | Results and Discussion

As a result of the studies, apricot drying methods and the parameters affected by these methods (namely aroma preservation, nutritional values, color protection, texture and structural features, flavor, shelf life, and production speed) were evaluated by six experts working as academicians in the Food Engineering Department. Microsoft Excel was used in the calculations and the arithmetic average of the expert opinions was taken. The main table of the study and the evaluation of an expert are shown in Table 1. Production speed is cost (minimization) oriented, while the others are benefit (maximization) oriented.

The parameters specified in the columns were evaluated by experts using the linguistic scale shown in Table 2 (Abdulvahitoğlu and Ertaş 2023).

The arithmetic average of the evaluations of six experts, which will be the basis of the calculation to be made with the Entropy technique within the principles stated above, is shown in Table 3. All parameters are expressed by making a benefit-side transformation.

As a result of the operations performed using Equations (1)–(6), the weights of the parameters affecting the selection of apricot drying methods were calculated as shown in Table 4.

#### 3.1 | TOPSIS

The initial matrix used in the TOPSIS technique is the same as the matrix used in the entropy technique. Here, the weights obtained by the Entropy technique are added to the matrix. The normalized matrix obtained using Equation (7) and the criterion weights are shown in Table 5.

The final order of apricot drying methods obtained by applying the steps of the TOPSIS technique (Equations 7–13) is given in Table 6.

According to the rankings of apricot drying methods using the TOPSIS technique, freeze drying gives the best results, while sun drying gives the worst results.

TABLE 2 | 1–5 Linguistic scale.

Value	Description
1	Very bad
2	Poor
3	Medium
4	Good
5	Very good

**TABLE 3** | The arithmetic mean of expert opinions.

	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
<b>Direction of criteria</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	2.500	2.500	2.667	3.333	3.000	3.000	3.000
Hot drying	2.333	3.000	2.667	3.167	4.000	2.833	3.333
Microwave drying	3.667	4.000	3.500	3.667	3.833	3.833	4.167
Freeze drying	5.000	4.833	4.500	4.667	5.000	4.667	3.333
Vacuum drying	4.000	3.833	3.833	4.000	4.333	3.667	3.500
Infrared drying	3.500	3.500	3.333	3.500	3.833	3.333	3.833

**TABLE 4** | Weights of parameters.

<b>Criteria</b>	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 5** | Normalized matrix and weights with the TOPSIS technique.

	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
<b>Direction of criteria</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	0.2824	0.2768	0.3131	0.3624	0.3028	0.3396	0.4897
Hot drying	0.2635	0.3322	0.3131	0.3443	0.4037	0.3207	0.4353
Microwave drying	0.4141	0.4429	0.4110	0.3986	0.3869	0.4339	0.2993
Freeze drying	0.5647	0.5352	0.5284	0.5073	0.5046	0.5282	0.4353
Vacuum drying	0.4518	0.4245	0.4501	0.4349	0.4374	0.4150	0.4081
Infrared drying	0.3953	0.3876	0.3914	0.3805	0.3869	0.3773	0.3537
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 6** | Ranking of apricot drying methods with TOPSIS technique.

<b>Drying apricot methods</b>	<b>Ranking</b>
Sun drying	6
Hot drying	5
Microwave drying	2
Freeze drying	1
Vacuum drying	3
Infrared drying	4

### 3.2 | COPRAS

The normalized matrix was created using Equations (14)–(20) in the COPRAS technique and the normalized matrix is shown in Table 7.

The final order of apricot drying methods obtained by applying the steps of the COPRAS technique is given in Table 8.

According to the rankings of apricot drying methods using the COPRAS technique, freeze drying gives the best results, while sun drying gives the worst results.

### 3.3 | MAUT

The normalized matrix was created using Equations (21)–(25) in the MAUT technique and the normalized matrix is shown in Table 9.

The final order of apricot drying methods obtained by applying the steps of the MAUT technique is given in Table 10.

According to the rankings of apricot drying methods using the MAUT technique, freeze drying gives the best results, while hot drying gives the worst results.

**TABLE 7** | Normalized matrix with COPRAS technique.

	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
<b>Direction of criteria</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	0.135	0.130	0.150	0.175	0.143	0.164	0.254
Hot drying	0.126	0.157	0.150	0.167	0.190	0.155	0.225
Microwave drying	0.198	0.209	0.196	0.193	0.183	0.209	0.155
Freeze drying	0.270	0.252	0.252	0.246	0.238	0.255	0.225
Vacuum drying	0.216	0.200	0.215	0.211	0.206	0.200	0.211
Infrared drying	0.189	0.183	0.187	0.184	0.183	0.182	0.183
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 8** | Ranking of apricot drying methods with COPRAS Technique.

<b>Drying apricot methods</b>	<b>Ranking</b>
Sun drying	6
Hot drying	5
Microwave drying	3
Freeze drying	1
Vacuum drying	2
Infrared drying	4

**TABLE 9** | Normalized matrix with MAUT technique.

	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
<b>Direction of criteria</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	0.062	0.000	0.000	0.111	-1.000	0.000	-0.400
Hot drying	0.000	0.214	0.000	0.000	0.000	-0.100	0.000
Microwave drying	0.500	0.643	0.455	0.333	-0.167	0.500	1.000
Freeze drying	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Vacuum drying	0.625	0.571	0.636	0.556	0.333	0.400	0.200
Infrared drying	0.438	0.429	0.364	0.222	-0.167	0.200	0.600
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

### 3.4 | MOORA

The normalized matrix created using Equations (26)–(29) in the MOORA technique and the normalized matrix is shown in Table 11.

The final order of apricot drying methods obtained by applying the steps of the MOORA technique is given in Table 12.

According to the rankings of apricot drying methods using the MOORA technique, freeze drying gives the best results, while sun drying gives the worst results.

### 3.5 | MAIRCA

The normalized matrix created using Equations (30)–(40) in the MAIRCA technique and the normalized matrix is shown in Table 13.

The final order of apricot drying methods obtained by applying the steps of the MAIRCA technique is given in Table 14.

According to the rankings of apricot drying methods using the MAIRCA technique, freeze drying gives the best results, while sun drying gives the worst results.

**TABLE 10** | Ranking of apricot drying methods with MAUT technique.

Drying apricot methods	Ranking
Sun drying	5
Hot drying	6
Microwave drying	3
Freeze drying	1
Vacuum drying	2
Infrared drying	4

**TABLE 11** | Normalized matrix with MOORA technique.

Direction of criteria	Aroma preservation	Nutritional values	Color protection	Texture and structural features	Flavor	Shelf life	Production speed
	Max.	Max.	Max.	Max.	Max.	Max.	Min.
Sun drying	0.282	0.277	0.313	0.362	0.303	0.340	0.490
Hot drying	0.264	0.332	0.313	0.344	0.404	0.321	0.435
Microwave drying	0.414	0.443	0.411	0.399	0.387	0.434	0.299
Freeze drying	0.565	0.535	0.528	0.507	0.505	0.528	0.435
Vacuum drying	0.452	0.424	0.450	0.435	0.437	0.415	0.408
Infrared drying	0.395	0.388	0.391	0.380	0.387	0.377	0.354
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 12** | Ranks of the apricot drying methods with MOORA technique.

Drying apricot methods	Ranking
Sun drying	6
Hot drying	5
Microwave drying	3
Freeze drying	1
Vacuum drying	2
Infrared drying	4

**TABLE 13** | Normalized matrix with MAIRCA technique.

Direction of criteria	Aroma preservation	Nutritional values	Color protection	Texture and structural features	Flavor	Shelf life	Production speed
	Max.	Max.	Max.	Max.	Max.	Max.	Min.
Sun drying	0.062	0.000	0.000	0.111	0.000	0.091	1.000
Hot drying	0.000	0.214	0.000	0.000	0.500	0.000	0.714
Microwave drying	0.500	0.643	0.455	0.333	0.417	0.545	0.000
Freeze drying	1.000	1.000	1.000	1.000	1.000	1.000	0.714
Vacuum drying	0.625	0.571	0.636	0.556	0.667	0.455	0.571
Infrared drying	0.438	0.429	0.364	0.222	0.417	0.273	0.286
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 14** | Ranks of the apricot drying methods with MAIRCA technique.

<b>Drying apricot methods</b>	<b>Ranking</b>
Sun drying	6
Hot drying	5
Microwave drying	3
Freeze drying	1
Vacuum drying	2
Infrared drying	4

**TABLE 15** | Normalized matrix with MOOSRA technique.

<b>Direction of criteria</b>	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	0.282	0.277	0.313	0.362	0.303	0.340	0.490
Hot drying	0.264	0.332	0.313	0.344	0.404	0.321	0.435
Microwave drying	0.414	0.443	0.411	0.399	0.387	0.434	0.299
Freeze drying	0.565	0.535	0.528	0.507	0.505	0.528	0.435
Vacuum drying	0.452	0.424	0.450	0.435	0.437	0.415	0.408
Infrared drying	0.395	0.388	0.391	0.380	0.387	0.377	0.354
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

**TABLE 16** | Ranks of the apricot drying methods with MOOSRA technique.

<b>Drying apricot methods</b>	<b>Ranking</b>
Sun drying	6
Hot drying	4
Microwave drying	1
Freeze drying	3
Vacuum drying	5
Infrared drying	2

**TABLE 17** | Normalized matrix with MABAC technique.

<b>Direction of criteria</b>	<b>Aroma preservation</b>	<b>Nutritional values</b>	<b>Color protection</b>	<b>Texture and structural features</b>	<b>Flavor</b>	<b>Shelf life</b>	<b>Production speed</b>
	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Max.</b>	<b>Min.</b>
Sun drying	0.062	0.000	0.000	0.111	0.000	0.091	1.000
Hot drying	0.000	0.214	0.000	0.000	0.500	0.000	0.714
Microwave drying	0.500	0.643	0.455	0.333	0.417	0.545	0.000
Freeze drying	1.000	1.000	1.000	1.000	1.000	1.000	0.714
Vacuum drying	0.625	0.571	0.636	0.556	0.667	0.455	0.571
Infrared drying	0.438	0.429	0.364	0.222	0.417	0.273	0.286
Weights	0.282	0.180	0.148	0.073	0.096	0.119	0.101

### 3.6 | MOOSRA

The normalized matrix created using Equations (40)–(44) in the MOOSRA technique and the normalized matrix is shown in Table 15.

The final order of apricot drying methods obtained by applying the steps of the MOOSRA technique is given in Table 16.

According to the rankings of apricot drying methods using the MOOSRA technique, Microwave drying gives the best results, while sun drying gives the worst results.

### 3.7 | MABAC

The normalized matrix was created using Equations (45)–(53) in the MABAC technique and the normalized matrix is shown in Table 17.

The final order of apricot drying methods obtained by applying the steps of the MABAC technique is given in Table 18.

According to the rankings of apricot drying methods using the MABAC technique, freeze drying gives the best results, while sun drying gives the worst results. Graphs of the ranking results of MCDM applications on apricot drying methods are shown in Figure 5.

### 3.8 | Borda Rule Application

The rankings made with seven different MCDM techniques were combined with the Borda rule. First, the board value of each technique was found with the Equation (54). Then, these values were added up to find the total board value of the options and the final ranking was made. The results of these operations are shown in Table 19.

TABLE 18 | Ranks of the apricot drying methods with the MABAC technique.

Drying apricot methods	Ranking
Sun drying	6
Hot drying	5
Microwave drying	3
Freeze drying	1
Vacuum drying	2
Infrared drying	4

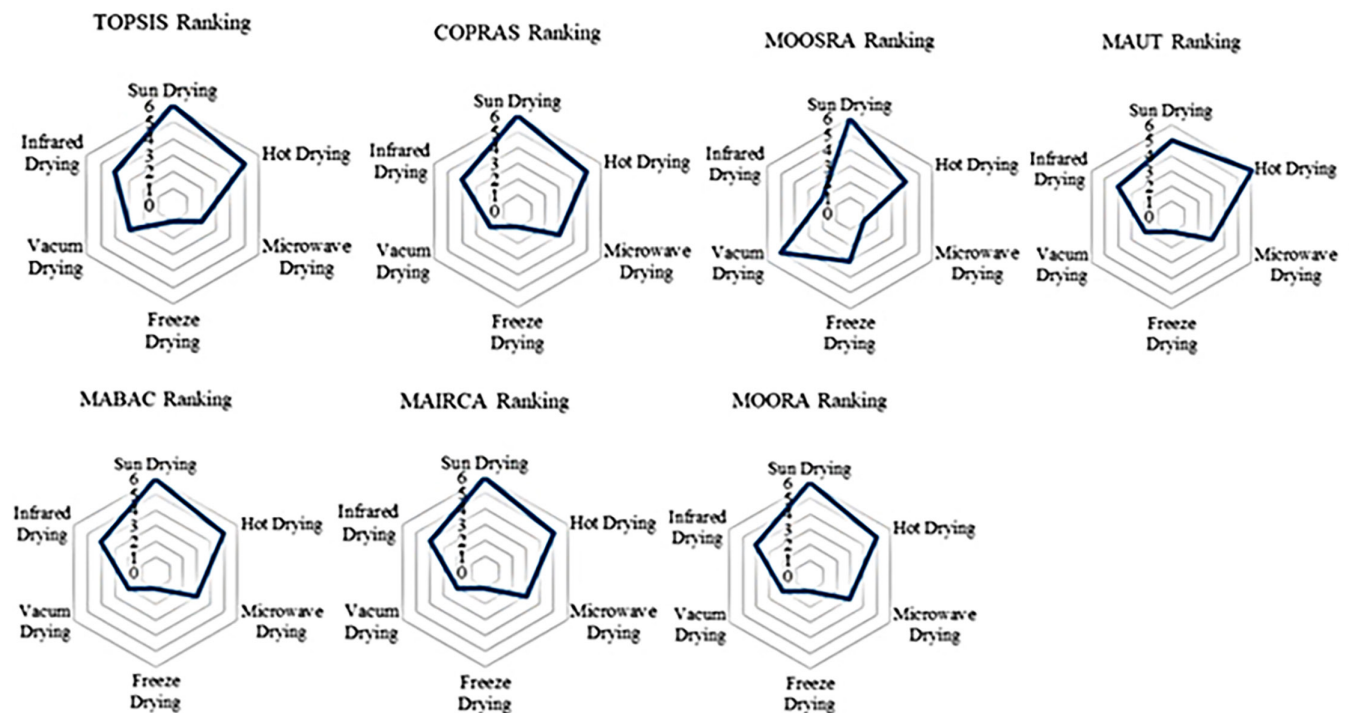


FIGURE 5 | Graphs of the ranking results of MCDM applications on apricot drying methods.

**TABLE 19** | Combining the results of MCDM techniques with the Borda rule.

	TOPSIS	Borda value	COPRAS	Borda value	MOORA	Borda value	MAUT	Borda value	MAIRCA	Borda value	MOOSRA	Borda value	MABAC	Borda value	Total Borda value	Borda final ranking
Sun drying	6	0	6	0	6	1	5	1	6	0	6	0	6	0	1	6
Hot drying	5	1	5	1	5	0	6	5	5	1	4	2	5	1	7	5
Microwave drying	2	4	3	3	3	3	3	3	3	3	1	5	3	3	24	2 or 3
Freeze drying	1	5	1	5	1	5	1	5	1	5	3	3	1	5	33	1
Vacuum drying	3	3	2	4	2	4	2	4	2	4	5	1	2	4	24	2 or 3
Infrared drying	4	2	4	2	4	2	4	4	4	2	2	4	4	2	16	4

As a result of the calculations made based on expert opinions, the most suitable drying method is Freeze Drying, as seen in Table 19. Vacuum Drying and Microwave Drying are shared two or three places with equal importance.

#### 4 | Conclusion

Foods are preserved in various ways for reasons such as the seasonal growth of some agricultural products and their consumption in other seasons, the storage of excess production, and the creation of food stocks for food safety. One method of preserving food is drying. Drying is the process of converting a product in liquid, solid, or semi-solid form into a solid product by reducing its moisture. This way, fresh foods are preserved without rotting or spoiling, and their shelf life is extended.

Many food drying methods have been developed since the beginning of humanity. These drying methods affect different properties of foods at different rates. For example, long-term sun drying, compared to other methods, can cause undesirable changes in the color and microbial structure of the products. New drying technologies have been developed to obtain higher quality products, resulting in significant improvements in dry product quality. Increased product quality has contributed to dried foods becoming valuable commercial products and the continuous development and importance of the dry food industry.

In the drying process, it is very important to know and adjust the structural properties of the product, its rehydration ability, and its initial and final moisture content. While different drying methods positively affect the quality of some products, they can negatively affect others. The drying method should be suitable for the structural and textural properties of the food to be dried and must meet the profit expected by the producer from the drying process, as well as the quality and taste expected by consumers from the product. Therefore, drying systems that produce results with different characteristics have been developed. Choosing the most suitable method according to the food type is a very difficult problem, as more than one criterion affecting the drying process must be evaluated systematically and consistently.

In this context, MCDM techniques are frequently used to make decision-making processes more transparent and to better cope with uncertainties. It is possible to solve complex problems more effectively and make more informed decisions with MCDM. In this study, the results obtained using entropy-based MCDM techniques were analyzed to provide decision support to producers in choosing the most appropriate apricot drying method.

Calculations made with seven different MCDM techniques based on expert opinions yielded similar results. The values obtained from these calculations were combined using the Borda rule, and it was concluded that the method with the highest score was the most appropriate.

According to the final result,

- The most appropriate apricot drying methods were determined to be freeze drying, vacuum drying, and microwave drying, respectively.

- These results show that, contrary to the popular perception that natural or traditional methods are organic or of better quality, the product parameters, especially nutritional values, of the products obtained as a result of drying using technological developments are at a higher level; In other words, the product quality is better.

## 5 | Future Works

Building on these results, future studies can utilize numerical data obtained from experiments conducted by researchers specializing in apricot drying, as well as customer preferences, applying MCDM techniques. This approach would allow for more objective outcomes based on experimental data. Additionally, sensitivity analysis could be performed by adjusting parameter values or modifying parameters, enabling the assessment of each parameter's impact on the results.

### Author Contributions

Data Curation: Nurten Cengiz. Formal analysis: Aslı Abdulvahitoğlu and Adnan Abdulvahitoğlu. Methodology: Aslı Abdulvahitoğlu and Adnan Abdulvahitoğlu. Visualization: Aslı Abdulvahitoğlu and Adnan Abdulvahitoğlu. Writing – original draft: Aslı Abdulvahitoğlu and Adnan Abdulvahitoğlu. Writing – review and editing: Aslı Abdulvahitoğlu, Adnan Abdulvahitoğlu and Nurten Cengiz.

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### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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