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Comparative Analysis of Different Drying Methods on Strawberry Aroma Compounds via Multi-Criteria Decision-Making Techniques

Nurten Cengiz [1], Aslı Abdulvahitoğlu [2,*] and Adnan Abdulvahitoğlu [3]

[1] Department of Food Engineering, Adana Alparslan Türkeş Science and Technology University, Adana 01250, Türkiye; nkurt@atu.edu.tr
[2] Department of Mechanical Engineering, Adana Alparslan Türkeş Science and Technology University, Adana 01250, Türkiye
[3] Department of Industrial Engineering, Mudanya University, Bursa 16940, Türkiye; abdulvahitoglu@gmail.com
* Correspondence: aabdulvahitoglu@atu.edu.tr

Abstract: Food and food safety, as one of the basic issues of human life, has made it necessary to store foods for a long time with the increasing population. One of the oldest and most common methods of extending the shelf life of food products is the drying process. The drying process contributes to the higher quality of foods in terms of physical, chemical, and microbial properties by ensuring that beneficial contents such as vitamins, minerals, and aroma compounds are better preserved. The aroma values of foods, which consist of taste and smell components, gain importance. In foods, the taste is determined by permanent components, while smell is determined by volatile components. The loss of volatile aroma compounds in the strawberry drying process negatively affects product quality. Small changes in aroma compounds can lead to significant differences in product taste. Therefore, strawberry aroma is a critical factor for consumer appeal and commercial success. In this study, the effects of drying methods on the aroma compounds of strawberry fruit were compared with Multi Criteria Decision Making (MCDM) techniques. In this study, PSI-based MCDM techniques were used to make the most appropriate choice among strawberry drying methods. The values of 23 distinct aroma compounds obtained with different drying methods applied to strawberry fruit were analyzed with 7 different MCDM techniques. The calculations gave similar results and these results were combined with the Borda rule. Accordingly, the drying methods with the highest scores were determined as freeze drying.

Keywords: food drying technologies; strawberry; aroma; MCDM; Borda rule

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1. Introduction

After harvesting, agricultural products begin to rot and deteriorate, with this process occurring more quickly in fresh fruits and vegetables. Foods not stored under proper conditions lose their nutritional value and result in economic losses. Throughout history, various methods have been employed to preserve food for extended periods, and one of the oldest and most common methods is drying. Drying not only facilitates the transportation and storage of foods but also preserves their nutritional value, extends their shelf life, and reduces storage costs [1]. Inappropriate food preservation methods not only lead to economic losses but also diminish quality and nutritional value, posing a significant threat to food safety [2]. Drying is a production method widely used in the food industry and other industries. The main purpose of the drying process is to improve the storage conditions of the products and extend their shelf life [3]. Fresh fruits and vegetables usually have high moisture content. Therefore, if they are not dried in time, they are at risk of mold and spoilage [4]. In addition, the costs of dried foods are generally lower compared to canned and frozen foods [5].

Food drying is an economical method that requires less labor and equipment compared to many other preservation techniques, making it particularly suitable for the long-term storage of fruits and vegetables. By reducing the moisture content in food, this method prevents the growth of microorganisms and preserves food without spoilage [1]. Dried foods can either be consumed directly or used as raw materials for other packaged food products.

Strawberry is one of the most consumed fruits with its attractive color, unique aroma, flavor, and high nutritional value, which grows almost everywhere in the World [6,7]. Agricultural experts report that farmers are expanding strawberry cultivation to meet the growing global demand for the world's 19th most popular fruit. According to the Food and Agriculture Organization (FAO), global strawberry production reached 12,933,872.48 tons in 2022 [8]. World production is projected to grow by 2.5% in 2024, reaching 13.2 million tons [9]. The leading countries in global strawberry production are listed in Table 1.

Table 1. Leading countries in world strawberry production [8].

Production (ton)	Country
3,364,007.58	China
1,261,890	United States of America
728,112	Türkiye
637,842.16	Egypt
568,271.93	Mexico
325,880	Spain
254,800	Russian Federation
199,400	Poland
192,889.29	Republic of Korea
183,922.5	Brazil
164,431.19	Japan

In 2022, Turkey ranked third in the world for strawberry production, as shown in Table 1. While most strawberries are consumed domestically in Turkey, exports have been steadily increasing. According to Trademark data, strawberry exports amounted to \$31,560,000 in 2022 and rose to \$37,130,000 in 2023 [10]. Given their significant economic and commercial value both in Turkey and globally, strawberries were chosen as the focus of this study. A literature review of strawberry-related research published in the Web of Science database was conducted using Vosviewer software (version 1.6.20), and the countries involved in these studies are presented in Figure 1.

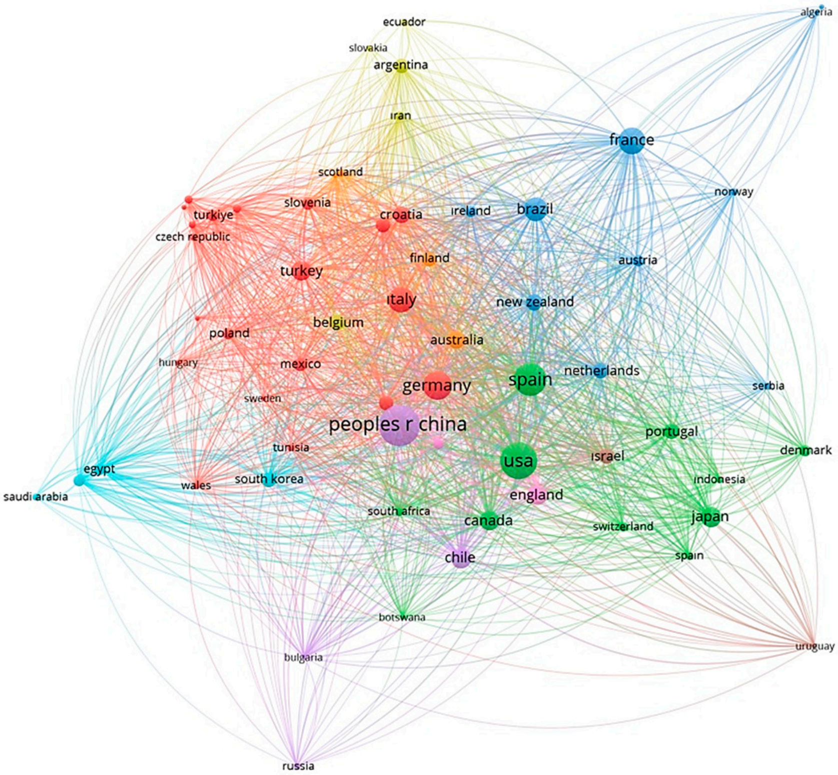

Figure 1. Countries where strawberry-themed studies have been conducted.

Strawberries are a fruit widely consumed fresh or processed with other foods around the world due to their high nutritional value. Just eight strawberries contain more vitamin C than an orange. In addition, they contain many beneficial nutrients such as potassium, manganese, iron, calcium, magnesium, folate, and other antioxidants. Another benefit of strawberries is that they are preferred by many people on a food diet due to their low glycemic index value [11]. The nutritional values of 100 g of strawberry fruit are shown in Figure 2. Known for their fresh and delicious taste, strawberries are highly appealing with their pleasant aroma and unique flavor. While predominantly consumed fresh, they can be preserved for extended periods through freezing and hold significant potential for industrial applications. Nutritionally, strawberries are a low-calorie fruit with limited energy, protein, fat, and carbohydrate content [9].

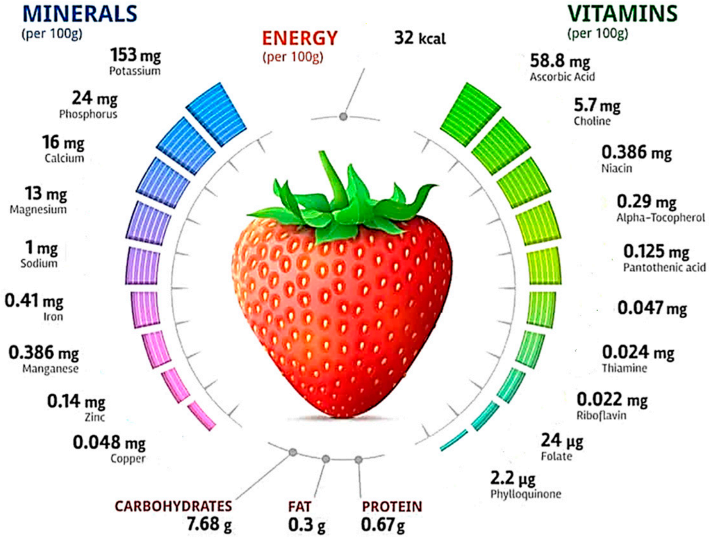

Figure 2. Nutritional values of 100 g strawberries [9].

In addition, the bioactive components of strawberries, which offer numerous health benefits, have significantly increased their demand and economic significance in the market [12]. Consequently, strawberries stand out as one of the most sought-after fruits, available in fresh, frozen, and dried forms, as well as in processed products such as jam [13,14]. Strawberry is a fruit rich in water and has high physiological activity after harvest. During storage, transpiration and respiration cause the consumption of organic matter, leading to water loss and deterioration. This makes it difficult to store strawberries for a long time. Therefore, strawberries are often used as a model fruit for preservation research [15]. Due to its perishable nature, fresh strawberries are prone to rapid deterioration, which can result in significant economic losses. In addition, the short harvest season of strawberries and therefore its unavailability throughout the year limits its commercial use and consumption. Drying strawberries is an excellent way to retain their nutritional value, prolong their shelf life, and broaden their applications [16]. Drying, which is widely employed in the food sector, inhibits microbiological development and increases shelf life by lowering water content. Furthermore, it reduces transportation and storage expenses while maintaining the nutritional content and flavor of the fruit [17]. Consumers are particularly attracted to the unique flavor and attractive red color of these fruits. The flavor is the result of a combination of aroma, taste, and mouthfeel. The appealing aroma of strawberries is based on a complex mixture of volatile compounds such as esters, aldehydes, alcohol, ketones, furanones, and terpenes [18]. Therefore, the preservation of these volatile compounds during the drying process becomes important.

Different technologies are being developed and used to better preserve and store the color, flavor, textural, and structural properties of foods, as well as their nutritional value. These methods are widely used in strawberry drying. Depending on the type of food and the desired quality, various methods such as sun drying, oven drying, vacuum drying, freeze drying, and shade air drying are employed [19]. Each drying method has its own advantages and disadvantages, and these methods can impact food safety and quality in different ways.

Different strawberry drying methods have different positive and negative effects on the product. Traditional methods have negative effects such as loss of nutritional value, and formation of toxic gases and microorganisms [20]. Technological drying methods contribute to increasing the drying quality by providing a controlled drying environment and effective use of heat [21]. The choice of the optimum drying method is very important in terms of reducing the negative effects of the methods used in drying fresh vegetables and fruits and increasing their positive effects [22,23]. The main drying methods used in strawberry drying are explained below.

Shade Air Drying: Shade air drying is a method of drying food products and herbs in a shaded area with adequate air circulation. This method prevents exposure to direct sunlight to preserve sensitive compounds (vitamins, antioxidants, pigments). However, shade drying is generally slower than sun drying or other methods and can increase the risk of microbial contamination. This method is especially preferred for sensitive products such as herbs, fruits, and vegetables, where preservation of quality is important [17,19].

Oven Drying: Oven drying is the process of reducing moisture in foods by using an oven at a certain temperature and time. This method is widely preferred to extend the shelf life of foods and prevent them from spoiling [24]. It is usually used for ingredients such as vegetables, fruits and meat. Since the temperature and time can be easily controlled, the uniformity of the drying process increases [25]. In addition, this method helps preserve the texture and color of the food. Especially when applied at low temperatures, vitamins, and other nutrients are better preserved [26].

Microwave drying: This method, which is used especially for drying products with high moisture and water content by converting electromagnetic energy into heat, increases quality and efficiency together with hot or vacuum drying. It is an important advantage that it reduces costs while increasing the process speed and quality. The greatest advantage of this method is that heat is effectively and equally transferred to the interior of the food thanks to high conductivity [27]. In addition, reaching the required temperature quickly significantly increases production speed [28].

Freeze drying: Freeze drying is the method that best preserves product freshness. Water and moisture in the food are removed by sublimation, microbial and other spoilage are prevented and high quality is provided. However, high cost limits the use of this method. Flavor and color change are less compared to other drying methods [29].

The visuals of strawberries dried using different drying methods are presented in Figure 3 [14,30,31].

Fresh Strawberry Shade air dried Microwave dried

Oven dried 60 °C Oven dried 45 °C Freeze dried

Figure 3. The visuals of strawberries dried using different drying methods [14,30,31].

Experts are working on the use of these methods and the changes in product properties. Some of these are aimed at determining the effects of dried foods on aroma compounds. It is seen that studies have been carried out on the investigation of volatile compounds and ellagic acid formation in strawberry fruit [32], modeling approaches used in drying [33], aroma formation during the ripening stage of strawberries [34], design of solar food dryers [35], analysis of aroma compounds in strawberry storage [15], the effect of different drying methods on drying characteristics [17], the effect of pasteurization and storage conditions on straw-berry aroma components [36], effect of drying process on product properties [37], effect of microwave and hot air drying methods on product color [38], drying of straw-berries with radiofrequency cold plasma [39], use of infrared radiation in pre-drying processes [40] etc. in the literature. In these studies, a drying method has generally been compared with others and the effects on various properties of dried foods have been examined. However, no study has been found to compare the methods used in strawberry drying with each other according to certain parameters or to determine the drying method that preserves the aroma values at the optimum level.

It is extremely important to analyze the effects of drying methods on the aroma compounds of dried food and to determine the drying method that ensures the optimum preservation of product properties. Ideally, the nutritional values, texture, flavor, and aroma of foods preserved through various methods should remain unchanged. In particular, maintaining aroma values is crucial, especially for commercial products. As a result, selecting the optimal preservation method in food drying has become increasingly important. At this point, the use of Multi-Criteria Decision Making (MCDM) techniques, which allow for an integrated evaluation of different and diverse study results, stands out. In the literature, it is seen that studies have been conducted on the comparison of drinking water brands with MCDM techniques [41], analysis of agricultural production methods with MCDM [42], comparative analysis of apricot drying methods [1], factors causing vegetable and fruit losses in the supply chain [43], risk analysis with MCDM in food packaging [44], determination of the importance levels of potential sun drying problems with MCDM [45], etc. In addition, strawberry-themed studies were meticulously explored using the Web of Science database, and the insights gathered were analyzed and visualized through Vosviewer for a comprehensive evaluation, as shown in Figure 4.

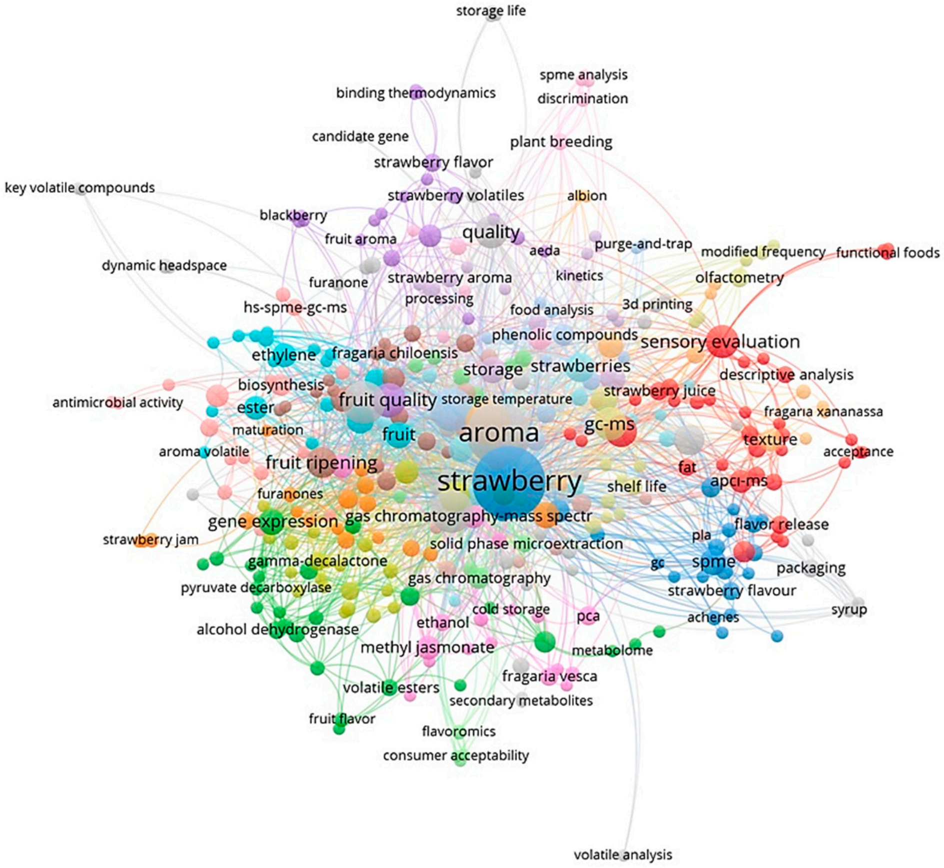

Figure 4. Strawberry-themed works.

However, no study has been identified that compares the effects of different strawberry drying methods on the product's aroma compounds using MCDM techniques or provides decision support to producers in selecting a drying method and to consumers in choosing the most suitable dried strawberry product for purchase. Therefore, the study aims to compare different drying methods for their effects on strawberry aroma compounds using MCDM techniques.

The stages of this study, which aim to identify strawberry aroma compounds, evaluate the most commonly used strawberry drying techniques and their effects on product aroma, and determine the drying method that best preserves strawberry aroma compounds, are illustrated in Figure 5.

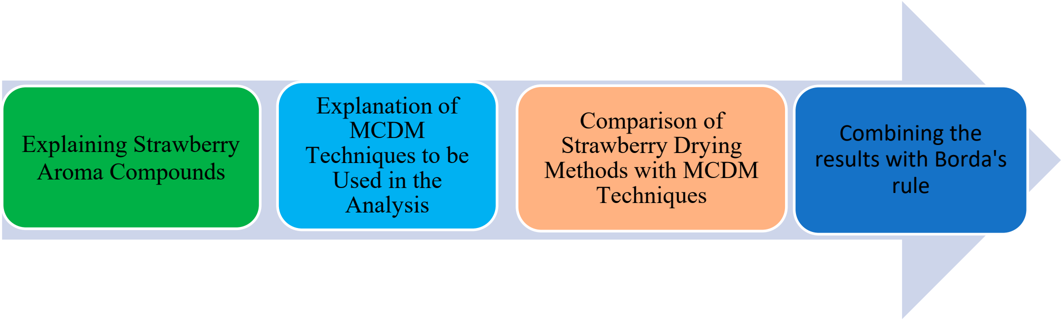

Figure 5. Stages of the study.

2. Materials and Methods

Strawberries (*Fragaria* spp.) are perennial plants from the Rosaceae family, known for their delicious taste and high nutritional value. The content and concentration of aroma compounds, which contribute to the fruit's characteristic taste and smell, serve as key indicators of strawberry quality [32]. Alongside their vibrant color and distinctive aroma, the sensory quality of strawberries is attributed to a combination of vitamin C and antioxidant compounds such as flavonoids and ellagic acid (EA) [46]. EA, found in natural sources such as strawberries, blackberries, pomegranates, and almonds, is a major phenolic acid that is a dimeric condensation product of gallic acid. Due to its potent anticarcinogenic, antithrombotic, anti-inflammatory, and neurodegenerative disease-protective qualities, ellagic acid is crucial in the prevention and treatment of several chronic illnesses, including cancer, diabetes, metabolic syndrome, and Alzheimer's [32].

Studies have confirmed that almost all of the aroma compounds in fruits are derived from non-volatile biosynthetic precursors such as fatty acids, sugars, amino acids, and secondary metabolites [47].

In strawberry fruits, aroma is an important organoleptic property that directly affects consumption and determines consumer preferences. It is also one of the quality indicators of the fruit [48]. Strawberry aroma plays a key role in the commercial success as well as the attractiveness of the fruit [49]. This unique aroma is caused by a variety of volatile organic compounds (VOCs), including esters, alcohols, ketones, furans, terpenes, aldehydes, and sulfur compounds. Even small changes in volatile compounds can significantly affect the taste of strawberries. Although these compounds constitute only 0.001–0.01% of the strawberry weight, they are the main factors determining aroma characteristics and consumer appeal [7,50].

The aroma profile of strawberries is quite complex. To date, more than 360 volatile compounds have been identified in fresh strawberries [7,14,51]. However, not all of these compounds affect aroma. Odor activity value (OAV) is generally used to evaluate the effect of compounds. Compounds with OAV values higher than 1 are considered important volatile compounds [52]. It is known that compounds with high OAV values in strawberries make significant contributions to aroma [7].

The main volatile compounds found in strawberries are esters, furanones, lactones, terpenes, aldehydes, and minor components.

Esters are the most dominant volatile compound group that defines the aroma profile of strawberries. Studies have determined that esters constitute 25% to 90% of the total volatiles in strawberries [7]. Esters are the main source of fruity and floral odors in strawberries and contribute significantly to the aroma of ripe strawberries [14,48]. Prominent esters include methyl butanoate, ethyl butanoate, methyl hexanoate, and hexyl acetate [53,54]. In contrast, ethyl acetate has been associated with off-flavor notes [55].

Furanones contribute greatly to strawberry aroma despite being present in low concentrations. The two main furanone compounds of strawberries are known as furaneol

(2,5-dimethyl-4-hydroxy-3(2H)-furanone) and mesifuran (2,5-dimethyl-4-methoxy-3(2H)-furanone). These compounds are characterized by their sweet and caramel-like aroma profiles and enhance the “fresh strawberry” sensation [51,54].

Lactones are an intense and important group of compounds in the aroma profile of strawberries. γ-decalactone, which has a peach and strawberry-like odor, was found in high amounts in some strawberry varieties [6]. γ-decalactone was detected as the main lactone in freeze-dried and oven-dried strawberries, while γ-butyrolactone was prominent in microwave-dried samples [14].

Terpenes contribute to the floral and citrus notes in strawberry aroma. The monoterpene linalool and the sesquiterpene nerolidol are among the most important volatile terpene compounds in cultivated strawberry varieties. Linalool generally provides a citrus and floral aroma, while nerolidol carries fir/pine notes [7]. Wild strawberries contain different terpenes such as α-pinene and β-myrcene.

Aldehydes such as hexanal, (E)-2-hexenal, and nonanal in strawberries are responsible for green/herbal aroma profiles [51]. These compounds are also the cornerstone of the “fresh strawberry” taste [6]. Heat-sensitive compounds such as furfural and 5-hydroxymethylfurfural (HMF) are only produced in high-temperature applications such as oven or microwave drying [14].

Minor Components: Volatile organic acids make smaller contributions to the aroma profile of strawberries. These compounds are generally complementary elements of the aroma [6].

The aroma of foods consists of taste and odor components. Persistent components determine taste, while volatile components determine smell. Strawberries, which are a product rich in aroma, lose their volatile components during drying, which negatively affects quality [56]. Aroma compounds in strawberries may vary depending on the processing and drying methods used. In particular, freeze drying provides better preservation of volatile components, while heat-based methods may cause some aroma compounds to disappear or undesirable compounds to form.

Therefore, the selection of appropriate drying and processing techniques is of great importance to preserve aroma quality. In this context, 23 aroma compounds found in strawberries were considered and a table was created from the data obtained from the literature. It is desired that the first seven of the compounds specified in the table are in low amounts in the product and the other sixteen are in high amounts [6,7,14,51,53,55].

Table 2 below presents the key aroma compounds of both fresh strawberries and those dried using various methods, based on findings from the literature [14].

Table 2. Strawberry drying methods and aroma compounds values [14].

	Ethyl Acetate	**Nonanal**	**5-Hydroxymethylfurfural**	**Acetic Acid**	**Octanoic Acid**	***α*-Terpineol**	**Furfural**	**Mesifurane**	**Furaneol**	***γ*-Butyrolactone**	***γ*-Decalactone**	**Methyl Butanoate**	**Ethyl Butanoate**	**(*E*)-Nerolidol**	**Methyl Hexanoate**	**Ethyl Hexanoate**	**Hexyl Acetate**	**Methyl Octanoate**	**Ethyl Octanoate**	**Hexanal**	**(*E*)-2-Hexenal**	**Heptanal**	**Linalol**
Fresh	2.560	0.180	0	0.060	0	0.240	0	0.080	0.020	3.110	0.890	0.240	0.110	5.130	0.120	2.170	12.680	0.020	0.010	0.140	0.240	0	11.960
Shade-Air Dried	2.500	1.760	0	1.690	0.090	0.350	0	8.470	1.920	4.330	8.600	0	1.100	9.650	0.190	18.540	1.520	0	1.760	0.200	0	0.030	4.400

Microwave Dried	0	4.270	0.060	0	0.110	2.100	3.410	1.580	0	4.720	3.150	0	0	11.04	0	0.110	0	0	0	1.250	0	0.110	7.150
Oven-Dried (60 °C)	0	4.370	0.150	2.150	0	1.450	11.750	0.810	0.020	3.150	1.280	0	0.270	8.970	0.250	9.910	0.630	0.050	0.540	0.320	0	0.220	6.990
Oven-Dried (45 °C)	0	6.480	0.040	7.830	0.570	0.570	0.440	9.300	1.890	1.670	4.780	0	0.060	10.78	0.370	10.89	0.760	0.550	1.160	0.500	0.190	0.170	2.460
Freeze-Dried	0.290	1.830	0	0	0.130	1.720	0	3.230	0.040	1.850	12.140	0.090	0.040	17.140	1.950	0.790	4.660	0.590	0.280	0.150	0	0.120	16.430

In the following tables, these aroma compounds are symbolized as follows:

AC1: Ethyl acetate
AC2: Nonanal
AC3: 5-Hydroxymethylfurfural
AC4: Acetic acid
AC5: Octanoic acid
AC6: α-Terpineol
AC7: Furfural
AC8: Mesifurane
AC9: Furaneol
AC10: γ-Butyrolactone
AC11: γ-Decalactone
AC12: Methyl butanoate
AC13: Ethyl butanoate
AC14: (E)-Nerolidol
AC15: Methyl hexanoate
AC16: Ethyl hexanoate
AC17: Hexyl acetate
AC18: Methyl octanoate
AC19: Ethyl octanoate
AC20: Hexanal
AC21: (E)-2-Hexenal
AC22: Heptanal
AC23: Linalool

Drying Methods are symbolized as follows:

F: Fresh,
D1: Shade air Dried,
D2: Microwave dried,
D3: Oven-Dried (60 °C),
D4: Oven dried (45 °C),
D5: Freeze Dried

2.1. Multi-Criteria Decision Making Methods (MCDM)

MCDM methods, which are used in almost every area of life, allow decision-makers to make evaluations by considering a large number of factors. MCDM methods are used in decision problems that require ranking or weighting. There are approximately 200 published methods in the literature [1,57]. In MCDM techniques (methods), operations are generally carried out by following the steps shown in Figure 6 below. Microsoft Excel was used in the calculations

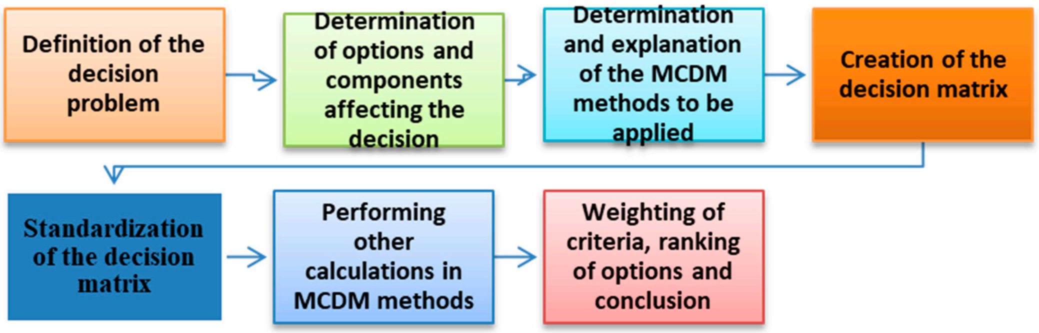

Figure 6. Multi-Criteria Decision Making process [1].

2.1.1. PSI (Preference Selection Index) Technique

PSI, one of the MCDM techniques, was first developed by Maniya and Bhatt in 2010 and applied to a material selection problem [58]. PSI solves with a simple, easy, and systematic calculation. Due to this feature, it is a useful method for determining the importance levels of criteria in situations where decision-making is difficult and complex [59]. The PSI technique finds the variance values indicating the importance levels of each option by making variance-based calculations for each component calculates the preference index and makes the final ranking. The steps of the PSI technique are explained below in order [58].

In this study, the importance levels of aroma compounds were determined using the PSI technique which has 4 steps by using Equations (1)–(7) [59].

Step 1. Creating the decision matrix X: The matrix X in Equation (1), which consists of m rows and n columns, is created.

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

Step 2. Normalizing the decision matrix. The normalized matrix is derived from decision matrix (1) using Equation (2) for maximization-oriented criteria and Equation (3) for minimization-oriented criteria.

$$R_{ij} = \frac{x_{ij}}{x_{j,max}};\ \forall\, i,j\ x_{j,max} = max\{x_{ij}\};\ \forall\, i,j \tag{2}$$

$$R_{ij} = \frac{x_{j,min}}{x_{ij}};\ \forall\, i,j\ x_{j,min} = min\{x_{ij}\};\ \forall\, i,j \tag{3}$$

Step 3. Calculating the preference variance values ($\boldsymbol{PV_i}$). These values are calculated using Equation (4). $\overline{R_J}$ calculated using Equation (5) represents the arithmetic mean of each row of the normalized matrix.

$$PV_j = \textstyle\sum_{i=1}^{N}\left[R_{ij} - \bar{R}_j\right]^2 \tag{4}$$

$$\overline{R_J} = \tfrac{1}{N}\textstyle\sum_{i=1}^{N} R_{ij} \tag{5}$$

Step 4. Calculation of the general preference value ($\boldsymbol{\psi_j}$). After the deviation in the preference values is found in Equation (6), the importance levels of the preference values are calculated in Equation (7).

$$\varphi_j = \left|1 - PV_j\right| \tag{6}$$

$$\psi_{j} = \frac{\emptyset_j}{\sum_{i=1}^{M} \emptyset_j} \tag{7}$$

The ψ_j values, calculated with the PSI technique, express the importance levels of aroma compounds.

2.1.2. COPRAS (The Complex Proportional Assessment) Technique

COPRAS was developed by Zavadskas and Kaklauskas in 1996 and is used to evaluate the criteria of the options by taking into account the benefit and cost objectives [60]. Its biggest advantage is that it compares the options and expresses proportionally how good or bad they are compared to each other. The technique has 6 steps and can be implemented by using the Equations (8)–(13) [60–62].

Step 1. Creating the decision matrix: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. Normalizing the decision matrix. The normalized matrix is derived from decision matrix (1) using Equation (8)

$$X_{ij}^{*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{8}$$

Step 3. Weighting the normalized matrix: The normalized matrix is weighted with Equation (9). In this context, the normalized matrix is multiplied by the weights obtained by the PSI method.

$$r_{ij} = x_{ij}^{*} w_j \tag{9}$$

Step 4. The sum of the criteria values: The sum of the criteria values is calculated by using Equation (10) for the benefit (maximum) oriented criteria and Equation (11) for the cost (minimum) oriented criteria.

$$S_i^{+}=\sum_{j=1}^{k} r_{ij} \tag{10}$$

$$S_i^{-}=\sum_{j=k+1}^{k} r_{ij} \tag{11}$$

Step 5. Relative weights of the options: The relative weights of the options are calculated using Equation (12).

$$Q_i = S_i^{+} + \frac{\sum_{i=1}^{m} S_i^{-}}{S_i^{-}\sum_{i=1}^{m}\left(\frac{1}{S_i^{-}}\right)} \tag{12}$$

Step 6: **Calculating the performance index of the option**s: The performance indices of each alternative are determined and ranked using Equation (13).

$$P_i = \left(\frac{Q_i}{Q_{max}}\right) * 100 \tag{13}$$

The P_i values of the options are ranked from biggest to smallest.

2.1.3. MOORA (Multi Objective Optimization on the Basis of Ratio Analysis) Technique

MOORA is an MCDM technique that was first developed by Brauers and can be successfully applied to solve various complex decision-making problems [63]. The biggest advantage of the technique is that it offers the opportunity to evaluate the criteria where the maximum value is better and the criteria where the minimum value is preferred together. The MOORA technique is implemented with four steps by using Equations (14)–(16) [64].

Step 1. Creating the decision matrix: In the ratio method, the initial (decision) matrix shown in Equation (1) is created.

Step 2. Matrix normalization: Normalization is performed by using Equation (14), where i = 1, 2, …, m is the number of alternatives, j = 1, 2, …, n is the number of criteria (objectives).

$$\mathrm{x_{ij}}^{*} = \frac{\mathrm{x_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{m}} \mathrm{x_{ij}}^{2}}} \tag{14}$$

Step 3. Weighing normalization matrix: Weighted normalized matrix values ($v_{\mathrm{i}J}$) are created using Equation (15) by multiplying each of the normalized matrix values by the weight of the criterion (w_J). w_j criteria weights were calculated using the PSI method.

$$v_{ij} = w_j * x_{ij}^{*} \tag{15}$$

Step 4. Determination of utility function of the options: In the decision matrix, the minimum goal values are subtracted from the maximum goal values of the criteria specified at the beginning. Equation (16) is used for this operation.

$$y_i^{*} = \sum_{j=1}^{g} v_{ij} - \sum_{j=g+1}^{n} v_{ij} \tag{16}$$

y_i^{*} i are the values that the options take according to the criteria evaluation. The process is completed by sorting the y_i^{*} values from biggest to smallest.

2.1.4. MAIRCA (Multi Attributive Ideal Real Comparative Analysis) Technique

MAIRCA, introduced to the MCDM literature by Gigovic and his colleagues, is a technique that identifies the gaps between ideal and empirical ratings [65]. By summing the gaps for each criterion, the total gap value for decision alternatives is calculated. At the end of the application, the alternative with the values closest to the ideal ratings, i.e., the one with the least total gap value, is determined as the best option. The MAIRCA technique is implemented with seven steps by using Equations (17)–(26) [66,67].

Step 1. Creating the decision matrix: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. Normalizing the decision matrix. The normalized matrix is derived from decision matrix (1) using Equation (18) for maximization-oriented criteria and Equation (19) for minimization-oriented criteria. The normalized matrix shown in Equation (20) is obtained.

$$n_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \tag{17}$$

$$n_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \tag{18}$$

$$N = \begin{bmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{m1} & \cdots & n_{mn} \end{bmatrix} \tag{19}$$

Step 3. Determination of selection probabilities $(\boldsymbol{P_i})$. It is calculated using Equation (20).

$$P_i = P_{i+1} = \cdots = P_m = 1/m \tag{20}$$

Step 4. Creation of the theoretical evaluation matrix. The theoretical evaluation matrix is calculated using Equation (21).

$$t_{ij} = P_i * w_{ij} \tag{21}$$

Step 5. Creation of the real evaluation matrix. The R real evaluation matrix shown in Equation (24) is created with Equation (22).

$$r_{ij} = t_{ij} * n_{ij} \tag{22}$$

$$R = \begin{bmatrix} t_{11}n_{11} & \cdots & t_{1n}n_{1n} \\ \vdots & \ddots & \vdots \\ t_{11}n_{m1} & \cdots & t_{mn}n_{mn} \end{bmatrix} \tag{23}$$

Step 6: Formation of the Total Difference Matrix: The difference matrix shown in Equation (25) is created using Equation (24).

$$G = T - R \tag{24}$$

$$G = \begin{bmatrix} t_{11} - r_{11} & \cdots & t_{1n} - r_{1n} \\ \vdots & \ddots & \vdots \\ t_{m1} - r_{m1} & \cdots & t_{mn} - r_{mn} \end{bmatrix} \tag{25}$$

Step 7. Calculation of criterion function values of alternatives. The criterion function is calculated with Equation (26)

$$Q_i = \sum_j^n g_{ij} \tag{26}$$

The process is completed by sorting the Q_i values of the options from smallest to biggest.

2.1.5. MOOSRA (Multi-Objective Optimization Based on Simple Ratio Analysis) Technique

MOOSRA, developed by Das et al. in 2012, is preferred due to its short calculation time, few mathematical operations, high reliability, and simple applicability [68]. While the first two steps of the method are similar to the MOORA technique, it differs in the 3rd step by comparing the maximization and minimization. The MOOSRA technique is implemented with four steps by using Equations (27)–(29) [68,69].

Step 1. Creating the decision matrix: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. **Normalizing the decision matrix**. The normalized matrix is derived from decision matrix (1) using Equation (27)

$$x_{ij}^{*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^{2}} \tag{27}$$

Step 3. Weighting the normalized matrix: The normalized matrix is weighted with Equation (28). In this context, the normalized matrix is multiplied by the weights (w_j) obtained by the PSI method.

$$a_{ij} = x_{ij}^{*}.w_j \tag{28}$$

Step 4. Calculating the benefit scores of the alternatives: The total benefit score (Y_i) of each alternative is calculated using Formula (29). The results are sorted from largest to smallest.

$$Y_i = \frac{\sum_{j}^{g} x_{ij}^{*}.w_j}{\sum_{j'=g+1}^{n} x_{ij'}^{*}.w_j} \tag{29}$$

$j = 1,2,\ldots,g$ for maximization,

$j' = g+1, g+2,\ldots,n$ for minimization

The process is completed by sorting the Y_i values of the options from biggest to smallest.

2.1.6. MABAC (Multi-Attributive Border Approximation Area Comparison) Technique

Developed by Pamučar and Ćirović in 2015, MABAC evaluates decision options by taking into account the distance of the criteria to the border proximity areas [70]. MABAC is an MCDM technique that aims to select the best alternative in a problem with many criteria in institutional and individual decision-making processes. MABAC is implemented with six steps by using Equations (30)–(37) [70,71].

Step 1. Creating the decision matrix: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. **Normalizing the decision matrix**: The normalized matrix is derived from decision matrix (1) using Equation (31) for maximization-oriented criteria and Equation (30) for minimization-oriented criteria.

$$r_{ij} = \frac{X_{ij} - X_j^{min}}{X_j^{max} - X_j^{min}} \tag{30}$$

$$r_{ij} = \frac{X_{ij} - X_j^{max}}{X_j^{min} - X_j^{max}} \tag{31}$$

Step 3. Weighting the normalized matrix: The normalized matrix is weighted with Equation (32). In this context, the normalized matrix is multiplied by the weights (w_j) obtained by the PSI method.

$$V_{ij} = W_j * \left(1 + r_{ij}\right) \tag{32}$$

Step 4. Obtaining the boundary proximity matrix. Using Equation (33), the boundary proximity area matrix (G) shown in Equation (34) is obtained.

$$g_i = \left(\prod_{i=1}^{m} V_{ij}\right)^{1/m} \tag{33}$$

$$G = [g_i]_{1*n} \tag{34}$$

Step 5. Determining the distances of the alternatives from the boundary proximity values. These distances are calculated using Equations (35) and (36).

$$Q = (v_i - G) = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \cdots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \cdots & v_{1n} - g_n \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} - g_2 & v_{m2} - g_2 & \cdots & v_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1m} \\ q_{21} & q_{22} & \cdots & q_{2m} \\ \vdots & & \ddots & \vdots \\ q_{n1} & q_{n2} & \cdots & q_{nm} \end{bmatrix} \tag{35}$$

$$A_i \in \begin{cases} G^+ \; if \; q_{ij} > 0 \\ G \; if \; q_{ij} = 0 \\ G \; if \; q_{ij} < 0 \end{cases} \tag{36}$$

Step 6. Ranking the alternatives: The alternatives specified in the decision matrix X are ranked using Equation (37).

$$S_{\mathrm{i}} = \sum_{j=1}^{n} q_{ij} \tag{37}$$

The process is completed by sorting the S_i values of the options from biggest to smallest.

2.1.7. WPM (Weighted Product Method) Technique

Simple and easy to apply, WPM determines the overall score of each option based on the weighted multiplication of the criteria values of the options. (Therefore, in this study, to prevent zero values from negatively affecting the results, calculations were performed by using the value 0.00001, which is significantly smaller than the other values, in the WPM and OWA methods.) In this way, the performance values of the options are found. The WPM technique is applied with four steps by using Equations (38)–(41) [72,73].

Step 1. Creating the decision matrix: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. Normalizing the matrix. Since the criteria are multiplied by each other in this method, no additional normalization process is applied.

Step 3. Creating the weighted decision matrix. The decision matrix is weighted with the Equations (38)–(40).

$$n_{ij} = x_{ij}^{w_j} \tag{38}$$

$$n_{ij} = x_{ij}^{-w_j} \tag{39}$$

$$w_j \geq 0, 0 \leq w_j \leq 1, \sum_{j=1}^{m} w_j = 1 \tag{40}$$

Step 4. Finding the multiplication points. The multiplication value of each option is found using the Equation (41).

$$V_i = \prod_{j=1}^{n} N_{\mathrm{i}J} \tag{41}$$

The process is completed by sorting the V_i values of the options from biggest to smallest.

2.1.8. OWA (Ordered Weighted Average) Operator

Developed by Ronald R. Yager in 1998, OWA is a technique that allows combining different pieces of information through the weights associated with these pieces [74,75]. OWA performs a parameterized aggregation between the largest and smallest values. The OWA operator covers criteria such as the highest value, the smallest value, and the average within the framework of special cases and provides an integrated structure according to different decision-making criteria. OWA is implemented with three steps by using the Equations (42)–(44) given below [74,75].

Step 1. **Creating the decision matrix**: The matrix X in Equation (1), which consists of m rows and n columns, is created.

Step 2. **Normalizing the decision matrix.** The normalized matrix is derived from decision matrix (1) using Equation (42) for maximization -oriented criteria and Equation (43) for minimization-oriented criteria.

$$R_{ij} = \frac{x_{ij}}{x_{j,max}};\ \text{for maximization oriented} \tag{42}$$

$$R_{ij} = \frac{x_{j,min}}{x_{ij}};\ \text{for minimization oriented} \tag{43}$$

Step 3. Calculating the OWA value for each alternative. The final result for each alternative is obtained by applying Equation (44) to compute the OWA values.

$$Z_i(w) = OWA(w)(r_{i1}, r_{i2}, \ldots, r_{i3}) = \sum_{j=1}^{m} w_j\, b_{ij} \tag{44}$$

Here, the values b_{ij} $(b_1 \geq b_2 \geq \cdots \geq b_n)$ values are arranged in decreasing order from biggest to smallest. In this way, the process is completed.

2.1.9. Borda Rule

It is one of the voting methods of the social choice system developed by Borda in 1784. In this technique, different rankings are combined to obtain a single ranking [76]. According to Borda's Rule, the most preferred alternative is given (n-1) points, and the least preferred is given 0 points. Scoring is done using Equality (45) [77]. Borda's rule eliminates contradictions by combining the outputs of various techniques and creating a single ranking [66]. In this study, the results obtained with each MCDM technique will be scored with Borda's Rule, and then the scores of the techniques will be added to make the final ranking.

$$B_i = \sum_{k=1}^{r} m - a_{ik} \tag{45}$$

3. Results and Discussion

The aroma values of dried foods vary depending on the drying method. Using the PSI technique, these data were evaluated in an integrated manner to calculate the importance levels of the aroma values. The aroma compounds of strawberry which were tabulated in Table 2 were analyzed with MCDM techniques, and firstly the importance level of aroma compounds was found with the PSI technique. Then, COPRAS, MOORA, MOOSRA, MAIRCA MABAC, WPM, and OWA techniques were used to rank the options. The different rankings obtained with each technique were combined with the Borda rule. It is desired that the first seven of the aroma compounds specified in the table have minimum values and the others have maximum values.

3.1. Aroma Compound Weights in Strawberry Drying Method Selection Using PSI Technique

The normalization step was performed using Formulas 1–3 and obtained results tabulated in Table 3.

Table 3. Normalized matrix obtained by PSI technique.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.000	1.000	1.000	0.000	1.000	1.000	1.000	0.009	0.010	0.659	0.073	1.000	0.100	0.299	0.062	0.117	1.000	0.034	0.01	0.112	1.000	0.000	0.728
D1	0.000	0.102	1.000	0.000	0.000	0.686	1.000	0.911	1.000	0.917	0.708	0.000	1.000	0.563	0.097	1.000	0.120	0.000	1.76	0.160	0.000	0.136	0.268
D2	1.000	0.042	0.000	1.000	0.000	0.114	0.000	0.170	0.000	1.000	0.259	0.000	0.000	0.644	0.000	0.006	0.000	0.000	0.00001	1.000	0.000	0.500	0.435
D3	1.000	0.041	0.000	0.000	1.000	0.166	0.000	0.087	0.010	0.667	0.105	0.000	0.245	0.523	0.128	0.535	0.050	0.085	0.54	0.256	0.000	1.000	0.425
D4	1.000	0.028	0.000	0.000	0.000	0.421	0.000	1.000	0.984	0.354	0.394	0.000	0.055	0.629	0.190	0.587	0.060	0.932	1,16	0.400	0.792	0.773	0.150
D5	0.000	0.098	1.000	1.000	0.000	0.140	1.000	0.347	0.021	0.392	1.000	0.375	0.036	1.000	1.000	0.043	0.368	1.000	0,28	0.120	0.000	0.545	1.000

As a result of the operations performed using Formulas (4)–(7) specified in the PSI technique, the importance levels of strawberry aroma compounds were calculated as shown in Table 4.

Table 4. Importance levels of strawberry aroma compounds.

Aroma Compounds	***AC1***	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
Weight	0.03834	0.04484	0.03835	0.03976	0.03976	0.04564	0.03834	0.04324	0.04017	0.04816	0.04546	0.04409	0.04490	0.04891	0.04514	0.04453	0.04490	0.04110	0.04433	0.04619	0.04182	0.04509	0.04696

As a result of the calculations made using the PSI technique, the three most important strawberry aromas were determined as (E)-Nerolidol (AC14), γ-Butyrolactone (AC10) and Linalool (AC23), respectively.

3.2. Comparison of Strawberry Drying Methods with COPRAS Technique

In the COPRAS technique, the Formulas (8)–(13) were applied to the decision matrix. Table 5 shows the normalization matrix with COPRAS and Table 6 shows the order of strawberry drying methods.

Table 5. Normalized matrix with COPRAS.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.918	0.010	0.000	0.005	0.000	0.039	0.000	0.003	0.005	0.165	0.029	0.727	0.070	0.082	0.042	0.051	0.626	0.017	0.003	0.055	0.558	0.000	0.242
D1	0.896	0.094	0.000	0.145	0.100	0.057	0.000	0.361	0.494	0.230	0.279	0.000	0.696	0.154	0.066	0.437	0.075	0.000	0.469	0.078	0.000	0.046	0.089
D2	0.000	0.228	0.240	0.000	0.122	0.339	0.219	0.067	0.000	0.251	0.102	0.000	0.000	0.176	0.000	0.003	0.000	0.000	0.000	0.488	0.000	0.169	0.145

D3	0.000	0.234	0.600	0.184	0.000	0.234	0.753	0.035	0.005	0.167	0.042	0.000	0.171	0.143	0.087	0.234	0.031	0.041	0.144	0.125	0.000	0.338	0.142
D4	0.000	0.346	0.160	0.671	0.633	0.092	0.028	0.396	0.486	0.089	0.155	0.000	0.038	0.172	0.128	0.257	0.038	0.455	0.309	0.195	0.442	0.262	0.050
D5	0.104	0.098	0.000	0.000	0.144	0.278	0.000	0.138	0.010	0.098	0.394	0.273	0.025	0.273	0.677	0.019	0.230	0.488	0.075	0.059	0.000	0.185	0.333

Table 6. List of strawberry drying methods using the COPRAS technique.

Drying Strawberry Methods	Ranking
Fresh	3
Shade Air Dried	2
Microwave Dried	5
Oven Dried (60 °C)	6
Oven Dried (45 °C)	4
Freeze Dried	1

According to the results obtained, the best drying method was determined to be Freeze Drying and the least preferred one was the Oven Drying method (60 °C) for the COPRAS technique.

3.3. Comparison of Strawberry Drying Methods with MOORA Technique

In the MOORA technique, the Formulas (14)–(16) were applied to the decision matrix. Table 7 shows the normalization matrix with MOORA and Table 8 shows the order of strawberry drying methods.

Table 7. Normalized matrix with MOORA.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.713	0.019	0.000	0.007	0.000	0.076	0.000	0.006	0.007	0.380	0.056	0.936	0.096	0.190	0.060	0.091	0.930	0.025	0.005	0.099	0.784	0.000	0.515
D1	0.696	0.190	0.000	0.204	0.150	0.111	0.000	0.646	0.713	0.530	0.537	0.000	0.965	0.357	0.094	0.779	0.112	0.000	0.802	0.142	0.000	0.093	0.190
D2	0.000	0.461	0.361	0.000	0.183	0.665	0.279	0.121	0.000	0.577	0.197	0.000	0.000	0.408	0.000	0.005	0.000	0.000	0.000	0.885	0.000	0.340	0.308
D3	0.000	0.472	0.901	0.259	0.000	0.459	0.960	0.062	0.007	0.385	0.080	0.000	0.237	0.332	0.124	0.417	0.046	0.062	0.246	0.226	0.000	0.680	0.301
D4	0.000	0.700	0.240	0.944	0.947	0.180	0.036	0.709	0.701	0.204	0.298	0.000	0.053	0.399	0.184	0.458	0.056	0.680	0.529	0.354	0.621	0.525	0.106
D5	0.081	0.198	0.000	0.000	0.216	0.545	0.000	0.246	0.015	0.226	0.758	0.351	0.035	0.634	0.969	0.033	0.342	0.730	0.128	0.106	0.000	0.371	0.708

Table 8. List of strawberry drying methods using the MOORA technique.

Drying Strawberry Methods	Ranking
Fresh	3
Shade Air Dried	1
Microwave Dried	5
Oven Dried (60 °C)	6
Oven Dried (45 °C)	4
Freeze Dried	2

According to the results obtained, the best drying method was determined to be Shade Air Dried and the least preferred one was the Oven Drying method (60 °C).

3.4. Comparison of Strawberry Drying Methods with MAIRCA Technique

In the MAIRCA technique, the Formulas (17)–(26) were applied to the decision matrix. Table 9 shows the normalization matrix with MAIRCA and Table 10 shows the order of strawberry drying methods.

Table 9. Normalized matrix with MAIRCA.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.000	1.000	1.000	0.992	1.000	1.000	1.000	0.000	0.010	0.472	0.000	1.000	0.100	0.000	0.062	0.112	1.000	0.034	0.006	0.000	1.000	0.000	0.578
D1	0.023	0.749	1.000	0.784	0.842	0.941	1.000	0.910	1.000	0.872	0.685	0.000	1.000	0.376	0.097	1.000	0.070	0.000	1.000	0.054	0.000	0.136	0.118
D2	1.000	0.351	0.600	1.000	0.807	0.000	0.710	0.163	0.000	1.000	0.201	0.000	0.000	0.492	0.000	0.000	-0.050	0.000	0.000	1.000	0.000	0.500	0.285
D3	1.000	0.335	0.000	0.725	1.000	0.349	0.000	0.079	0.010	0.485	0.035	0.000	0.245	0.320	0.128	0.532	0.000	0.085	0.307	0.162	0.000	1.000	0.276
D4	1.000	0.000	0.733	0.000	0.000	0.823	0.963	1.000	0.984	0.000	0.346	0.000	0.055	0.470	0.190	13.646	0.010	0.932	0.659	0.324	0.792	0.773	0.000
D5	0.887	0.738	1.000	1.000	0.772	0.204	1.000	0.342	0.021	0.059	1.000	0.375	0.036	1.000	1.000	0.037	0.318	1.000	0.159	0.009	0.000	0.545	0.850

Table 10. List of strawberry drying methods using the MAIRCA technique.

Drying Strawberry Methods	Ranking
Fresh	4
Shade Air Dried	2
Microwave Dried	5
Oven Dried (60 °C)	6
Oven Dried (45 °C)	1
Freeze Dried	3

According to the results obtained, the best drying method was determined to be Oven-Dried (45 °C) and the least preferred one was Oven-Dried (60 °C) for MAIRCA.

3.5. Comparison of Strawberry Drying Methods with MOOSRA Technique

In the MOOSRA technique, the Formulas (27)–(29) were applied to the decision matrix. Table 11 shows the normalization matrix with MOOSRA and Table 12 shows the order of strawberry drying methods.

Table 11. Normalized matrix with MOOSRA.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.713	0.019	0.000	0.007	0.000	0.076	0.000	0.006	0.007	0.380	0.056	0.936	0.096	0.190	0.060	0.091	0.930	0.025	0.005	0.099	0.784	0.000	0.515
D1	0.696	0.190	0.000	0.204	0.150	0.111	0.000	0.646	0.713	0.530	0.537	0.000	0.965	0.357	0.094	0.779	0.112	0.000	0.802	0.142	0.000	0.093	0.190

D2	0.000	0.461	0.361	0.000	0.183	0.665	0.279	0.121	0.000	0.577	0.197	0.000	0.000	0.408	0.000	0.005	0.000	0.000	0.000	0.885	0.000	0.340	0.308
D3	0.000	0.472	0.901	0.259	0.000	0.459	0.960	0.062	0.007	0.385	0.080	0.000	0.237	0.332	0.124	0.417	0.046	0.062	0.246	0.226	0.000	0.680	0.301
D4	0.000	0.700	0.240	0.944	0.947	0.180	0.036	0.709	0.701	0.204	0.298	0.000	0.053	0.399	0.184	0.458	0.056	0.680	0.529	0.354	0.621	0.525	0.106
D5	0.081	0.198	0.000	0.000	0.216	0.545	0.000	0.246	0.015	0.226	0.758	0.351	0.035	0.634	0.969	0.033	0.342	0.730	0.128	0.106	0.000	0.371	0.708

Table 12. List of strawberry drying methods using the MOOSRA technique.

Drying Strawberry Methods	Ranking
Fresh	1
Shade Air Dried	3
Microwave Dried	5
Oven Dried (60 °C)	6
Oven Dried (45 °C)	4
Freeze Dried	2

According to the results obtained, the best aroma values were identified in Fresh and the least preferred one was the Oven Drying method (60 °C) for MOOSRA.

3.6. Comparison of Strawberry Drying Methods with MABAC Technique

In the MABAC technique, the Formulas (30)–(37) were applied to the decision matrix. Table 13 shows the normalization matrix with MABAC and Table 14 shows the order of strawberry drying methods.

Table 13. Normalized matrix with MABAC.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.713	0.019	0.000	0.007	0.000	0.076	0.000	0.006	0.007	0.380	0.056	0.936	0.096	0.190	0.060	0.091	0.930	0.025	0.005	0.099	0.784	0.000	0.515
D1	0.696	0.190	0.000	0.204	0.150	0.111	0.000	0.646	0.713	0.530	0.537	0.000	0.965	0.357	0.094	0.779	0.112	0.000	0.802	0.142	0.000	0.093	0.190
D2	0.000	0.461	0.361	0.000	0.183	0.665	0.279	0.121	0.000	0.577	0.197	0.000	0.000	0.408	0.000	0.005	0.000	0.000	0.000	0.885	0.000	0.340	0.308
D3	0.000	0.472	0.901	0.259	0.000	0.459	0.960	0.062	0.007	0.385	0.080	0.000	0.237	0.332	0.124	0.417	0.046	0.062	0.46	0.226	0.000	0.680	0.301
D4	0.000	0.700	0.240	0.944	0.947	0.180	0.036	0.709	0.701	0.204	0.298	0.000	0.053	0.399	0.184	0.458	0.056	0.680	0.529	0.354	0.621	0.525	0.106
D5	0.081	0.198	0.000	0.000	0.216	0.545	0.000	0.246	0.015	0.226	0.758	0.351	0.035	0.634	0.969	0.033	0.342	0.730	0.128	0.106	0.000	0.371	0.708

Table 14. List of strawberry drying methods using MABAC technique.

Drying Strawberry Methods	Ranking
Fresh	4
Shade Air Dried	2
Microwave Dried	5
Oven Dried (60 °C)	6
Oven Dried (45 °C)	1
Freeze Dried	3

According to the results obtained, the best drying method was determined to be oven-dried (45 °C) and the least preferred one was oven-dried method (60 °C) for MABAC.

3.7. Comparison of Strawberry Drying Methods with WPM Technique

In the WPM technique, the Formulas (38)–(41) were applied to the decision matrix. Table 15 shows the normalization matrix with WPM and Table 16 shows the order of strawberry drying methods.

Table 15. Normalized matrix with WPM.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.961	1.080	1.632	1.126	1.631	1.066	1.616	0.895	0.847	1.054	0.995	0.942	0.911	1.079	0.914	1.034	1.114	0.847	0.819	0.917	0.942	0.596	1.120
D1	0.962	0.975	1.632	0.978	1.108	1.048	1.616	1.098	1.028	1.071	1.100	0.618	1.004	1.112	0.932	1.136	1.018	0.613	1.025	0.932	0.615	0.854	1.070
D2	1.631	0.937	1.127	1.626	1.098	0.967	0.950	1.020	0.614	1.075	1.052	0.618	0.616	1.119	0.615	0.908	0.613	0.613	0.607	1.010	0.615	0.906	1.094
D3	1.631	0.936	1.084	0.968	1.631	0.983	0.902	0.991	0.847	1.055	1.011	0.618	0.946	1.108	0.943	1.106	0.981	0.880	0.974	0.951	0.615	0.934	1.093
D4	1.631	0.919	1.147	0.917	1.024	1.026	1.035	1.103	1.027	1.024	1.072	0.618	0.888	1.117	0.959	1.110	0.988	0.975	1.006	0.970	0.932	0.924	1.042
D5	1.054	0.973	1.632	1.626	1.091	0.976	1.616	1.053	0.873	1.029	1.117	0.904	0.873	1.142	1.029	0.990	1.068	0.978	0.946	0.920	0.615	0.909	1.136

Table 16. List of strawberry drying methods using WPM technique.

Drying Strawberry Methods	Ranking
Fresh	2
Shade Air Dried	4
Microwave Dried	6
Oven Dried (60 °C)	5
Oven Dried (45 °C)	3
Freeze Dried	1

According to the results obtained, the best drying method was determined to be Freeze Dried and the least preferred one was the Microwave Drying method for WPM.

3.8. Comparison of Strawberry Drying Methods with OWA Technique

In the OWA technique, the Formulas (42)–(44) were applied to the decision matrix. Table 17 shows the normalization matrix with OWA and Table 18 shows the order of strawberry drying methods.

Table 17. Normalized matrix with OWA.

	AC1	***AC2***	***AC3***	***AC4***	***AC5***	***AC6***	***AC7***	***AC8***	***AC9***	***AC10***	***AC11***	***AC12***	***AC13***	***AC14***	***AC15***	***AC16***	***AC17***	***AC18***	***AC19***	***AC20***	***AC21***	***AC22***	***AC23***
F	0.000	1.000	1.000	0.000	1.000	1.000	1.000	0.009	0.010	0.659	0.073	1.000	0.100	0.299	0.062	0.117	1.000	0.034	0,01	0.112	1.000	0.000	0.728
D1	0.000	0.102	1.000	0.000	0.000	0.686	1.000	0.911	1.000	0.917	0.708	0.000	1.000	0.563	0.097	1.000	0.120	0.000	1,76	0.160	0.000	0.136	0.268

D2	1.000	0.042	0.000	1.000	0.000	0.114	0.000	0.170	0.000	1.000	0.259	0.000	0.000	0.644	0.000	0.006	0.000	0.000	0.00001	1.000	0.000	0.500	0.435
D3	1.000	0.041	0.000	0.000	1.000	0.166	0.000	0.087	0.010	0.667	0.105	0.000	0.245	0.523	0.128	0.535	0.050	0.085	0,54	0.256	0.000	1.000	0.425
D4	1.000	0.028	0.000	0.000	0.000	0.421	0.000	1.000	0.984	0.354	0.394	0.000	0.055	0.629	0.190	0.587	0.060	0.932	1,16	0.400	0.792	0.773	0.150
D5	0.000	0.098	1.000	1.000	0.000	0.140	1.000	0.347	0.021	0.392	1.000	0.375	0.036	1.000	1.000	0.043	0.368	1.000	0,28	0.120	0.000	0.545	1.000

Table 18. List of strawberry drying methods using the OWA technique.

Drying Strawberry Methods	Ranking
Fresh	4
Shade Air Dried	3
Microwave Dried	6
Oven Dried (60 °C)	5
Oven Dried (45 °C)	1
Freeze Dried	2

According to the results obtained, the best drying method was determined to be the Oven Drying (45 °C) method and the least preferred one was the Microwave Drying method for OWA.

3.9. Combining the Results Obtained by MCDM Techniques with the Borda Rule

The rankings made with 7 different MCDM methods were combined with the Borda rule. First, the borda value of each method was found with Equation (45). Then, these values were added up to find the total borda value of the options and, the final ranking was made. The results of these operations are shown in Table 19.

Table 19. Combining the results of MCDM techniques with the Borda rule.

	MOOSRA	**Borda Value**	**MAIRCA**	**Borda Value**	**COPRAS**	**Borda Value**	**MOORA**	**Borda Value**	**MABAC**	**Borda Value**	**WPM**	**Borda Value**	**OWA**	**Borda Value**	**Total Borda Value**	**Borda Final Ranking**
Fresh	1	5	4	2	3	3	3	3	4	2	2	4	4	2	21	4
Shade-Air Dried	3	3	2	4	2	4	1	5	2	4	4	2	3	3	25	2
Microwave-Dried	5	1	5	1	5	1	5	1	5	1	6	0	6	0	5	5
Oven-Dried (60 °C)	6	0	6	0	6	0	6	0	6	0	5	1	5	1	2	6
Oven-Dried (45 °C)	4	2	1	5	4	2	4	2	1	5	3	3	1	5	24	3
Freeze-Dried	2	4	3	3	1	5	2	4	3	3	1	5	2	4	28	1

Freeze Drying emerged as a suitable drying method in the collective evaluation of the rankings obtained with the applied MCDM techniques using the Borda rule. On the other hand, in Table 19, Shade Air Dried is second, and Oven-Dried (45 °C) is third. Fresh fruit gives fourth place and Microwave drying and Oven Drying at 60 °C fifth and sixth place, respectively. These rankings are quite compatible with the literature. Abouelenein et al. (2021) found that fruity ester compounds were significantly reduced in microwave drying, oven drying at 60 °C, and oven drying at 45 °C [14]. Microwave drying was determined to be the method that reduced the ester content the most. In contrast, shade-drying and freeze-drying methods were reported to preserve ester compounds better. Also, Abouelenein et al. (2023) suggest that drying at low temperatures for a long time should be preferred to drying at high temperatures for a short time in order to obtain dried strawberries with a fruitier taste [30].

Furthermore, it was determined in this study that aroma values were best preserved in freeze-drying. It is stated in the literature that drying processes at temperatures of 50 °C and above have negative effects on food quality parameters and can especially lead to the loss of components such as color, aroma, and phenolic substances. This situation may negatively affect the overall quality of foods [78]

Furanone compounds were observed to increase especially in low-temperature drying (45 °C oven drying), shade drying, and freeze-drying processes. Furaneol was detected at low levels in samples obtained by oven drying at 60 °C but was not detected at all in the microwave drying method due to the high temperature. This was attributed to the fact that furaneol was not stable, depending on temperature and pH [52]. Jetti et al. (2007) stated that lactone levels increased significantly in samples dried by freeze and shade, and freeze drying gave the best results for terpene compounds [52]. These findings are consistent with the rankings obtained in this study.

Graphics of the ranking results of MCDM and Borda's rule are shown in Figure 7.

Although drying technologies are closely linked to the economy, employment, energy savings, and food safety in the food drying industry [79], this study does not address aspects such as the environmental impact and cost of drying methods within its scope. Instead, the evaluation focuses solely on the aroma values of dried strawberries. However, when examining drying methods from the perspectives of cost and environmental impact, it becomes evident that each method has its unique advantages and limitations. Shade drying, for instance, is a simple and cost-effective technique [80]. However, it presents challenges such as extended drying times, the need for ample space, and significant manpower requirements [81]. On the other hand, oven drying remains a widely utilized method due to its affordability [82]. The incorporation of microwaves in the food industry has revolutionized drying processes by reducing processing time and costs compared to traditional methods, while also preserving high sensory quality and minimizing nutritional degradation. Additionally, microwave-assisted drying is environmentally friendly [83–85]. In contrast, freeze drying, despite its ability to produce high-quality dried products, is hindered by significant energy demands and high operating costs due to prolonged drying times. This makes it the most expensive drying method, thereby limiting its broader application [86]. However, given the improved preservation of product quality, nutritional content, minerals, and fragrance qualities, this issue may be neglected. Furthermore, employing renewable energy for freeze-drying can have a favourable influence on both cost and environmental impact.

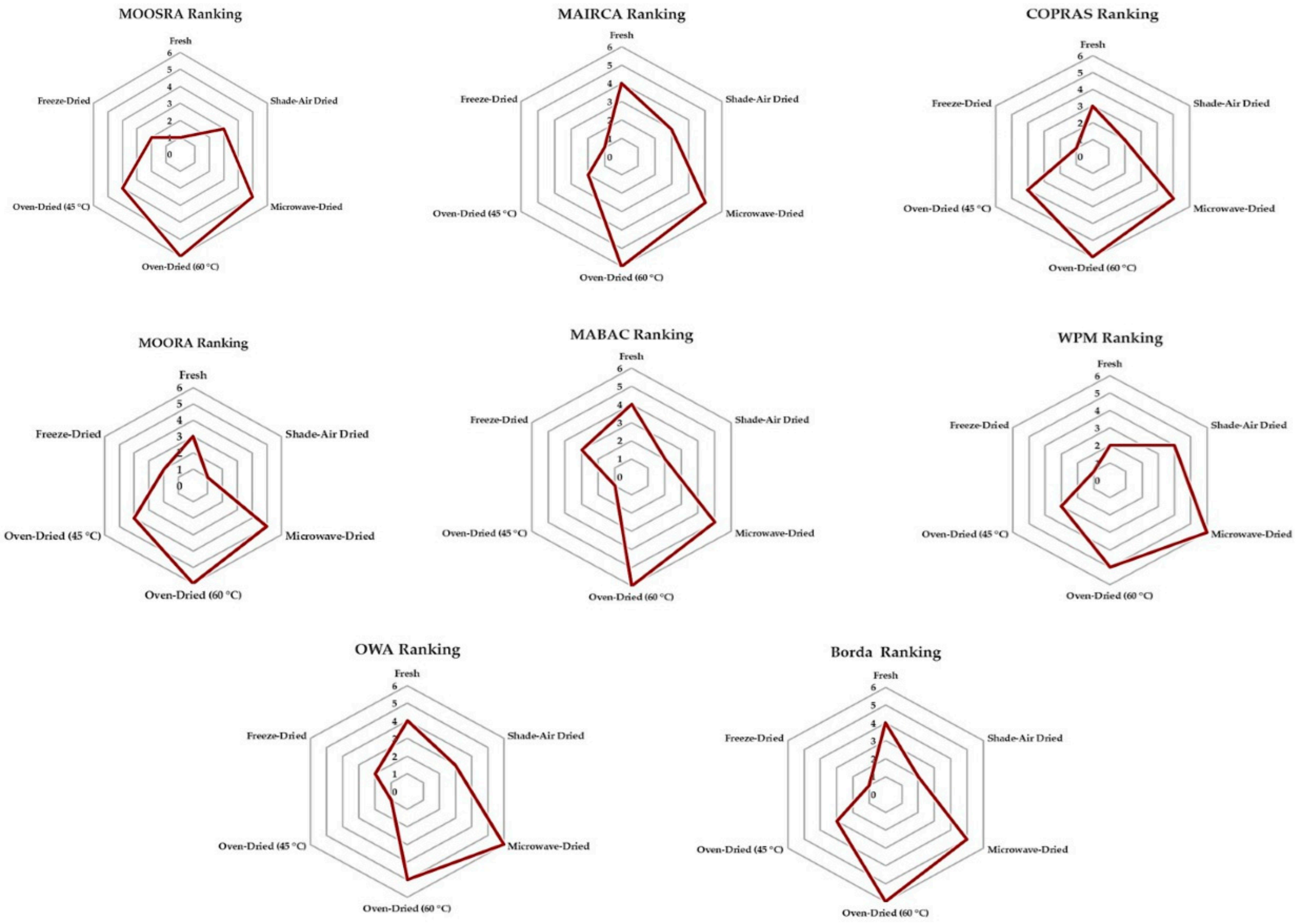

Figure 7. Graphics of the ranking results of MCDM and Borda rule.

4. Conclusions

Some agricultural products are cultivated seasonally and stored for year-round use, usually by drying. Drying lowers moisture content, which increases shelf life and prevents spoiling. Traditional techniques, such as oven drying at 60 °C, can reduce food quality by affecting colour, microbiological structure, and scent components, as demonstrated in strawberries. To overcome these difficulties, innovative drying technologies are constantly being developed, which improve product quality, increase commercial value, and emphasize the relevance of the drying industry. While some methods enhance quality, others may have adverse effects. Selecting the appropriate drying method requires considering the product's characteristics, production goals, and consumer expectations. Evaluating numerous aroma compounds systematically adds to the complexity of this decision-making process.

Multi-Criteria Decision Making (MCDM) techniques are frequently used to make decision-making processes more systematic and to manage uncertainties, such as in choosing strawberry drying methods. MCDM enables more effective solutions to complex problems and more informed decisions. In this study, PSI-based MCDM techniques were used to make the most appropriate choice among strawberry drying methods.

The values of 23 distinct aroma compounds obtained with different drying methods applied to strawberry fruit were analyzed with seven different MCDM techniques. The calculations gave similar results and these results were combined with the Borda rule. Accordingly, the drying methods with the highest scores were determined as freeze drying, shade drying, and oven drying at 45 °C, respectively. These findings revealed that the freeze-drying method, which has been frequently preferred in recent years but is quite high in terms of cost, gave the best results. On the other hand, the oven drying method performed at 60 °C in food drying was determined to be the method that gave the worst results because it caused the loss of a significant part of the aroma compounds. High temperatures caused the decrease or disappearance of many aroma compounds in the food content.

Future research can expand on the results by carrying out more thorough examinations of numerical data derived from strawberry drying tests using MCDM methodologies, such as nutritional content, mineral levels, and vitamin values. Further enriching the study might involve including expert comments on drying procedures, and cost and objectively assessing these subjective insights. Sensitivity studies can also be carried out with different parameters, enabling a thorough investigation of how each element affects the outcomes. These methods would help to build a more profound comprehension of the drying process and more objective, accurate findings.

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