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ARTICLE

Nutrient-rich elegance: A comprehensive evaluation of garden and cut rose cultivars for culinary and nutritional significance

Elegância rica em nutrientes: uma avaliação abrangente de cultivares de rosas de jardim e de corte quanto à relevância culinária e nutricional

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Abstract: Edible flowers have introduced a new dimension to healthy living. The rose can serve as a valuable food source. This research investigates the influence of properties included antioxidant capacity (AC), nutritional value (NV), biological value (BV), macro and micro-nutrients, pigments, organoleptic and consumer preferences properties on the selection of green space and cut rose cultivars, specifically 'Rainbows End,' 'Crimson Siluetta,' 'Hella,' 'Avalanche,' 'Dolce Vita,' and 'Samurai.' The selection criteria were weighed up using the Criteria Importance Through the Inter-Criteria Correlation (CRITIC) method, based on experts' point of view. Multi-criteria decision-making techniques, such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Additive Ratio Assessment (ARAS) and Weighted Aggregates Sum Product Assessment (WASPAS) were subsequently applied for ranking rose cultivars. Among the rose cultivars studied, the 'Hella' cultivar exhibited the highest biological value and pigment content, while the 'Crimson Siluetta' cultivar demonstrated the highest concentrations of macro and microelements, as well as the greatest antioxidant capacity. The 'Rainbows End' cultivar was found to have the highest nutritional value and superior organoleptic properties. Among the cut branch cultivars, the 'Samurai' cultivar, alongside the 'Crimson Siluetta', showed the highest levels of macro- and microelements. The findings indicated that all examined cultivars are rich in nutritious compounds suitable for human consumption. Notably, the 'Hella' cultivar emerged as the top choice, while 'Rainbows End' was ranked as the least preferred for inclusion in daily diets.
Keywords: biological value, consumers, nutritional value, organoleptic properties, preferences, rose cultivars.

Resumo: As flores comestíveis introduziram uma nova dimensão à vida saudável. A rosa pode servir como uma valiosa fonte alimentar. Esta pesquisa investiga a influência de propriedades como capacidade antioxidante (CA), valor nutricional (VN), valor biológico (VB), macro e micronutrientes, pigmentos, propriedades organolépticas e preferências dos consumidores na seleção de cultivares de rosas para espaços verdes e para corte, especificamente 'Rainbows End', 'Crimson Siluetta', 'Hella', 'Avalanche', 'Dolce Vita' e 'Samurai'. Os critérios de seleção foram ponderados utilizando o método CRITIC (Critérios de Importância por Correlação Intercritérios), com base na opinião de especialistas. Em seguida, técnicas de tomada de decisão multicritério, como o TOPSIS (Técnica de Ordem de Preferência por Similaridade para a Solução Ideal), o ARAS (Avaliação por Razão Aditiva) e o WASPAS (Soma de Produtos Agregados Ponderada) foram aplicadas para o ranqueamento das cultivares. Entre as cultivares estudadas, 'Hella' apresentou o maior valor biológico e teor de pigmentos, enquanto 'Crimson Siluetta' demonstrou as maiores concentrações de macro e micronutrientes, além da maior capacidade antioxidante. O cultivar 'Rainbows End' apresentou o maior valor nutricional e propriedades organolépticas superiores. Entre as cultivares de ramo de corte, 'Samurai', ao lado de 'Crimson Siluetta', apresentou os maiores níveis de macro e micronutrientes. Os resultados indicaram que todas as cultivares analisadas são ricas em compostos nutritivos adequados para o consumo humano. Notavelmente, 'Hella' destacou-se como a melhor opção, enquanto 'Rainbows End' foi classificada como a menos preferida para inclusão na dieta diária.
Palavras-chave: valor biológico, consumidores, valor nutricional, propriedades organolépticas, preferências, cultivares de rosa.

Introduction

Flowers are integral to Iran's cultural fabric, celebrated as wonders of nature and symbols of beauty within Persian literature. Beyond their ornamental appeal, flowers serve dual purposes, offering nutritional properties and biological benefits, with a culinary history spanning centuries (Stefaniak and Grzeszczuk, 2019). As culinary practices and decorative uses of flowers pique scientific curiosity, researchers have delved into the nutritional value of edible flowers. While traditionally valued for their medicinal attributes, recent emphasis has shifted towards recognizing the nutritional and phytochemical compounds present in edible flowers (Pinakin et al., 2020).

Globally, edible flowers have been sourced from 97 families, 100 genera, and 180 species. Typically consumed fresh, these flowers can also be transformed into various processed forms, including cakes, infusions, jams, salads, and beverages (Lu et al., 2016). In contemporary times, edible flowers have surged in popularity, captivating consumers with their sensory attributes such as color, taste, and fragrance. Recognizing the edible potential and nutritional properties of these flowers, alongside their inherent beauty advantages, has the potential to revolutionize the edible flower supply chain. Additionally, it can serve as a strategic measure to reduce waste in ornamental plants, including cut flowers (Kumari and Bhargava, 2021).

The rose, belonging to the Rosaceae family, stands as the foremost ornamental flower globally. The rose is rich in phenolic compounds, flavonoids, anthocyanins, carotenoids, and vitamins (Hegde et al., 2022; Kalisz et al., 2023). Furthermore, the rose emerges as an excellent contender for incorporation into modern cuisine as an edible flower, owing to its distinctive color and aroma (Kalisz et al., 2023).

In a study investigating the morphological characteristics, phytochemical properties, and biological activities of edible garden rose cultivars, Simin et al. (2023) concluded that roses stand as pivotal and economically significant garden plants. Beyond their captivating beauty and fragrance, roses emerge as rich sources of biologically active compounds, presenting potential health benefits. Additionally, all examined cultivars exhibit a pleasant aroma fit for human consumption, boasting high phenolic and vitamin C contents, robust antioxidant

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activity, and moderate neuroprotective effects, making them suitable for inclusion in daily diets. Concurrently, adding to this, Hegde et al. (2022) reported that rose petals contain significant amounts of potassium (K), phosphorus (P), and calcium (Ca), identifying them as the primary minerals present. Roses are found to be rich in carotenoids, organic acids, antioxidants, anticancer compounds, proteins, and carbohydrates. Beyond their nutritional and medicinal attributes, roses stand out as promising candidates for commercializing fresh edible foods due to their distinctive color and aroma. Netam (2021) highlights that there is widespread ignorance regarding the benefits of consuming edible flowers in many parts of the world, despite these natural resources having the potential to contribute significantly to human dietary needs. Salehi and Sorani (2023) delved into the nutritional potential of edible flowers as a novel aspect of promoting a healthy lifestyle. They asserted that edible flowers offer biologically active compounds, encompassing anthocyanin, carotenoids, polyphenols, vitamins, and minerals. Notably, the high content of phenolic compounds and antioxidant capacity have a favorable impact on diseases linked to oxidative stress. Consequently, there is a call for enhancing nutritional education to position flowers as functional foods, presenting a novel avenue for expanding food product offerings.

The main aim of this study was focused on role of organoleptic properties, nutritional and biological values, macro and micronutrients, pigments, antioxidant capacity, and consumer preferences in the selection of green space and cut rose cultivars.

Materials and Methods

Selection of plant species

The current research centers on three green space rose (*Rosa hybrida*) cultivars (‘Rainbows End,’ ‘Crimson Siluetta,’ and ‘Hella’) and three cut flower rose cultivars (‘Avalanche,’ ‘Dolce Vita,’ and ‘Samurai’).

All the rose cultivars utilized in this research were sourced from a reputable rose producer in Tehran province, Iran. Harvesting was meticulously performed at the early morning commercial stage, and the flowers were carefully transported to the experimental site at the Islamic Azad University of Rasht in suitable packaging, as well as for laboratory activities and surveys. Figure 1 visually depicts the assortment of edible roses under investigation.

Fig. 1. Edible roses studied (Research findings, 2023)

Data collection

The data necessary for assessing the edibility of the six chosen rose cultivars were gathered through a comprehensive multi-stage survey spanning from September 2022 to October 2023. To facilitate the selection process, the flowers were systematically evaluated against specific criteria, including nutritional value, biological value, macro and micronutrients, pigments, antioxidant capacity, organoleptic properties, and consumer preferences. For a visual representation of the research stages described in Fig. 2.

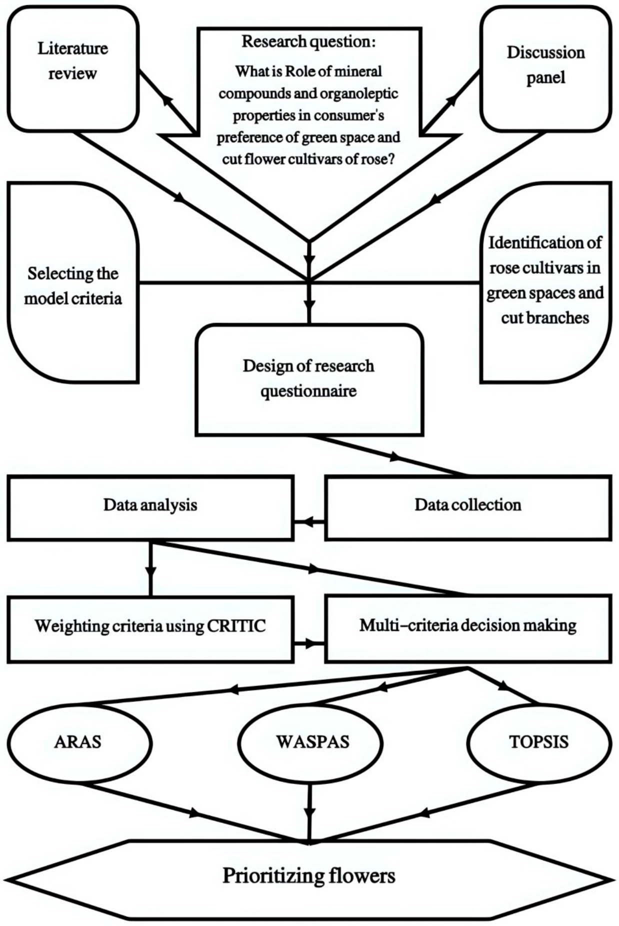

Fig. 2. Study steps (adapted from Firouzi et al. 2021).

The measurement of traits

Antioxidant capacity

To assess antioxidant capacity, a 50 µL plant extract was combined with 950 µL of 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution. This mixture was then left in the dark at room temperature for 15 minutes. Subsequently, the absorbance of the filtered samples was measured at 515 nm using an APEL PD-303UV spectrophotometer. The antioxidant capacity of the extracts was determined and expressed as percentage inhibition (%DPPHsc) using the following equation (Equ. 1) (Brand-Williams et al., 1995):

$$\%DPPHsc = (Acont - Asamp) \times 100/Acont \quad (1)$$

Nutritional value

The nutritional value of petal samples was calculated by the following equation 2:

$$\text{Nutrition value} = \frac{\text{mg Vit C/100g}}{10} + \left(\text{mg Vit}\frac{\text{A}}{\text{100g}}\right) + 5\,(\%\text{prot}) + 5(\text{mg Fe/100g}) + \frac{(\text{mgCa/100g})}{5} \quad (2)$$

Biological value

The biological value of petal samples was calculated by the following formula:

$$\text{Biological value} = \frac{\text{mg Vit C/100g}}{2} + (\text{mg Vit A/100g}) + \text{Raw fibers (g)} + \frac{(\text{mgCa/100g})}{100} + \frac{\text{mg Fe/100g}}{2} \quad (3)$$

Macro and micro-nutrients

For measuring the macro and micronutrient contents, including nitrogen, calcium (422.7 nm), phosphorus, potassium, magnesium (202.6 nm), sodium, sulfur, iron (248.3 nm), zinc (213.9 nm), copper (324.8 nm), boron (249.8 nm), manganese (279.5 nm), and nickel (352.5 nm), 1 g of ashed petals was blended with 3 mL of distilled water and 5 mL of 2 M hydrochloric acid. This mixture was then transferred to a bain-marie at 70 °C. After 15 minutes, the samples were taken out, allowed to cool at room temperature, and subsequently filtered with Whatman filter paper. The filtered solution›s volume was adjusted to 50 mL by adding distilled water. The resulting plant sample was utilized to determine mineral concentrations through atomic absorption, flame photometry, and spectrophotometry (Rengel and Romheld, 2000).

To incorporate the values obtained from measuring each element into the decision matrix, the studied flowers were ranked based on their measurements. This ranking considered factors such as the toxicity threshold of each nutrient and the desirability of higher amounts of each nutrient in each flower (Table 1 and Table 2). Subsequently, the mean ranks of the flowers concerning the macro and micronutrients were integrated into the decision matrix (Table 5).

Table 1. Macro elements measurements.

Cultivars	S (ppm)	N (%)	P (ppm)	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)
'Hella'	271 (4)[a]	0.8 (3)	26.73 (3)	186.27 (1)	11.48 (4)	33.83 (1)	7.48 (1)
'Crimson Siluetta'	227 (5)	0.6 (5.5)	30.0 (2)	158.56 (6)	11.1 5 (6)	27.53 (2)	7.13 (2)
'Rainbows End'	200 (6)	1.0 (1)	31.31 (1)	162.8 (4)	11.48 (4)	21.53 (4)	4.98 (4)
'Dolce Vita'	356 (1)	0.8 (3)	26.08 (4)	160.65 (5)	11.48 (4)	26.32 (3)	6.12 (3)
'Samurai'	286 (3)	0.6 (5.5)	23.46 (5)	184.16 (2)	11.91 (2)	20.4 (5)	4.16 (6)
'Avalanch'	298 (2)	0.8 (3)	13.01 (6)	164.92 (3)	14.04 (1)	20.36 (6)	4.25 (5)

[a] Numbers in parentheses represent the ranks assigned to each element based on quantitative measurements (higher amounts receiving the highest rank), after which the mean rank across all elements was calculated for each flower cultivar.

Table 2. Micro elements measurements.

Cultivars	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	B (ppm)
'Hella'	1.44 (1)[a]	0.33 (1)	0.11 (1)	2.51 (2)	0.009 (1.5)	0.007 (1)
'Crimson Siluetta'	0.88 (2)	0.15 (5)	0.07 (2)	2.76 (1)	0.006 (3.5)	0.005 (4.5)
'Rainbows End'	0.62 (3)	0.19 (2)	0.04 (3)	1.82 (5)	0.006 (3.5)	0.006 (2.5)
'Dolce Vita'	0.2 (5)	0.18 (3)	0.03 (4.5)	1.99 (4)	0.0 (5.5)	0.005 (4.5)
'Samurai'	0.11 (6)	0.14 (6)	0.03 (4.5)	2.13 (3)	0.009 (1.5)	0.006 (2.5)
'Avalanch'	0.23 (4)	0.16 (4)	0.02 (6)	1.07 (6)	0.0 (5.5)	0.004(6)

[a]Numbers in parentheses indicate the ranks assigned to each element based on quantitative measurements, with higher values receiving higher ranks. The average rank across all elements was then calculated for each flower cultivar.

Pigments

To measure the pigments, carotenoids, and anthocyanin content in the petals, 0.5 g of fresh petals was initially extracted using acidic methanol. The resulting extract was then filtered using Whatman grade 2 filter paper, and its absorbance was recorded at 535 nm for anthocyanin and at 440, 645, and 663 nm for carotenoids with an APEL PD-103UV spectrophotometer. The amounts of pigments, carotenoids, and anthocyanin were determined using the following equations (Mazumdar and Majumder, 2003) (Table 3):

$$4.69 \times A_{440} - 0.268 \times (20.2)\, A_{645} + (8.02)\, A_{663} = \text{petals' carotenoids (micrograms per gram of wet weight)}$$

$$\text{(mg/100 g of fresh tissue) anthocyanin} = \frac{e \times b \times c}{d \times a} \times 100$$

To integrate the values obtained from pigment measurements into the decision matrix, the pigments were ranked, and the mean ranks of the flowers were incorporated into the matrix (Table 5).

Table 3. Pigments, carotenoids, and anthocyanins measurements.

Cultivars	Carotenoid (μg g FW^{-1})	Anthocyanin (mg 100 g FW^{-1})
'Hella'	2.08 (6)[a]	5.09 (5)
'Crimson Siluetta'	2.26 (4)	82.48 (2)
'Rainbows End'	2.48 (1.5)	25.97 (3)
'Dolce Vita'	2.48 (1.5)	13.24 (4)
'Samurai'	2.33 (3)	85.03 (1)
'Avalanch'	2.19 (5)	4.58 (6)

[a]Numbers in parentheses represent the ranks assigned to each element based on quantitative measurements (with higher amounts receiving the highest rank), after which the mean rank across all elements was calculated for each flower cultivar

Organoleptic properties

To assess the organoleptic properties of the studied rose cultivars, a questionnaire was devised based on Kelley et al.'s (2002a, 2002b) research and administered to 15 experts with experience in the sensory properties of foods. The experts were tasked with evaluating the studied roses by responding to questions such as whether the flower is appealing in terms of shape, size, and color, whether it possesses a pleasant aroma, whether it has a delicate texture, and whether it is delicious. Responses were scored on a scale from completely disagree (0) to completely agree (10). Additionally, the experts were asked to identify the dominant taste of each rose (sweet, sour, bitter, astringent, sweet-and-sour, and unknown) and to associate the taste of the roses with specific foods. The experts received fresh and hygienically packaged roses along with a bottle of water. They tasted each of the six flowers sequentially, followed by a sip of water to neutralize the taste, and then completed the questionnaire. The average scores derived from the respondents' evaluations for each flower were incorporated as the score for its sensory characteristics in the decision matrix. Figure 3 illustrates the organoleptic properties of the studied rose cultivars (Table 5).

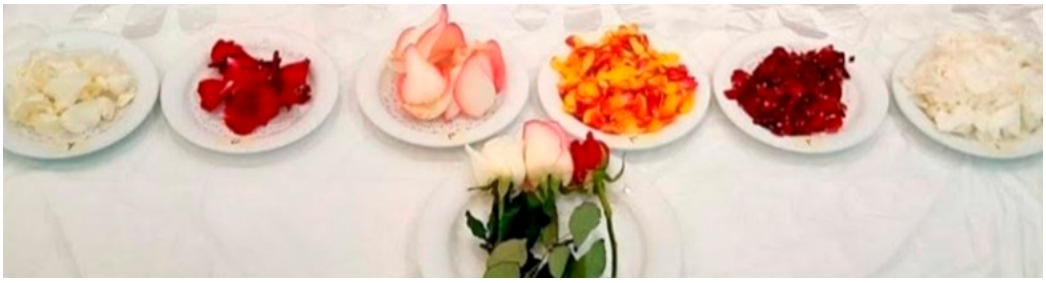

Fig. 3. Organoleptic properties of the studied rose cultivars (Research findings, 2023).

Consumers' preferences

To gauge consumers' preferences, another questionnaire, administered online, was distributed to 216 consumers randomly selected from both men and women with diverse socio-economic backgrounds. This questionnaire comprised two sections. The first section focused on respondents' demographic characteristics, including age, gender, educational level, field of study, and occupation. The second section included inquiries about how edible rose flowers were used, included as in food preparation and decoration, pickling or jam making, salad preparation and decoration, purchasing food consumption, cultivation for food consumption, recommending to others, or as infusions. The questions were dichotomous, assigning a score of one if the respondent was willing to consume each of the studied flowers and a score of zero if unwilling. The sum of the scores for each respondent determined the willingness to consume flowers. The average score of the respondents was then included in the decision matrix as the preference to consume each flower (Table 5).

Multi-criteria decision-making (MCDM) techniques

The edible roses under study were ranked based on the established criteria using multi-criteria decision-making (MCDM) techniques. Weights were assigned to the criteria through the CRITIC method. Recognizing that decision-making methods have distinct advantages and disadvantages, TOPSIS, ARAS, and WASPAS techniques were employed as compensatory methods to leverage the strengths of each technique. A brief description of their calculation methods is outlined below. The TOPSIS technique entails a comparison of weighted reference solutions, namely a positive-ideal solution (S+) and a negative-ideal solution (S-). The overall importance of the options is calculated through their simultaneous measurement. The steps in TOPSIS, as listed by Rudnik (2017), include:

Building a weighted normalized decision matrix. Determining a positive ideal solution (S+). Determining a negative-ideal solution (S-). Calculating the distances of each alternative from the positive-ideal solution (S+) and negative-ideal solution (S-). Calculating the relative proximity to the ideal solution.

The ARAS method, standing for Additive Ratio Assessment, incorporates a utility function to determine the complex relative efficiency of a feasible alternative, considering the relative influence of values and weights of the main criteria in a project. One advantage of ARAS is its ease in selecting the best option, making it one of the favorable Multi-Criteria Decision Making (MCDM) techniques. In this method, the best alternative is identified as the one with the longest distance from negative factors and the shortest distance from positive factors. As outlined by Zavadskas and Turskis (2010), the ARAS technique follows these steps:

Building a Decision Matrix Model (DMM) decision matrix. Normalizing the initial values of all criteria (Xij values of the normalized X decision matrix), including the criteria with maximum and minimum preferred values. Comparing the dimensionless values of criteria that initially have different dimensions. Defining the matrix with normal weight X, where the weight values of Wj are typically determined through expert evaluation, and the sum of the Wj weights is limited. Determining the optimal function values in the end.

The WASPAS technique is a Multi-Criteria Decision Making (MCDM) method that utilizes both the Weighted Product Method (WPM) and Weighted Sum Method (WSM) to identify the optimal alternative. Introduced by Ghorabaee et al. (2016), this method distinguishes itself from similar approaches by incorporating both WPM and WSM simultaneously. While these two techniques are typically used independently to measure and rank alternatives, WASPAS combines them. The general steps in the WASPAS technique are as follows:

Forming a Decision Matrix: The first step involves creating a decision matrix.

Assigning Weights to Criteria: Criteria are assigned weights using one of the MCDM methods. Normalizing the Decision Matrix: The initial decision matrix is normalized. Calculating Total Relative Values: The first and second total relative values are calculated using the Weighted Sum Method (WSM). WASPAS employs the strengths of both WPM and WSM to simultaneously assess and rank alternatives in the decision-making process. Qi is the combined optimal value calculated by the equation and is used to rank the alternatives. The alternative with the highest Qi is the best and is ranked first.

Weight assignment to criteria

In most of the Multi-Criteria Decision Making (MCDM) problems, understanding the relative importance of criteria, whose sum is equal to one (normalized), is crucial. This relative importance serves to gauge the priority of a criterion in comparison to others during the decision-making process (Asgarzadeh et al., 2014). In this study, the CRITIC method was employed to determine the weights assigned to the criteria. To assign weights to the criteria, an online questionnaire was devised, comprising eight indices: organoleptic properties, nutritional value, biological value, macro and micro-nutrients, pigments, antioxidant capacity, and edible rose consumers' preferences. Six experts specializing in agricultural sciences, horticulture, and food industries were invited to estimate the importance of these indices in selecting edible flowers on a scale of 1 - 10. The CRITIC method, a weighting technique grounded in the correlation and standard deviation of the decision matrix data and utilizing the linear normalization method, was then employed. The CRITIC method is a highly suitable and practical approach for determining the weights of criteria. This method is well-suited for use in conjunction with other Multi-Criteria Decision Making (MCDM) techniques (Habibi and Afaridi, 2022). The steps of the CRITIC method are as follows:

The first step is to form a decision matrix. By the term "decision matrix" we mean a matrix in which the rows and columns include the alternatives and the criteria, respectively. This matrix contains *m* alternatives and *n* criteria and is generally written as follows:

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

The following equations (4, 5, and 6) are used to measure data correlation and determine the initial and final weights of the criteria linearly:

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (4)$$

$$C_j = \sigma_j \sum_{i=1}^{m} (1 - r_{ij}) \quad (5)$$

$$w_j = \frac{C_j}{\sum_{i=1}^{m} C_i} \quad (6)$$

Results

Decision-making models for selecting edible flowers require suitable weights of various criteria based on the views of experts. The results of such analysis indicate that organoleptic properties (0.175), antioxidant capacity (0.163), and nutritional value (0.146) were the most important criteria from the experts' point of view (Table 4). This assessment emphasizes the significance of these three criteria in determining the suitability of edible flowers for consumption. Organoleptic properties refer to sensory attributes such as taste, aroma, and texture. These qualities play a crucial role in influencing consumers' preferences and perceptions of food products. Additionally, antioxidant capacity is essential due to its potential health benefits in reducing oxidative damage caused by free radicals in the body. Furthermore, nutritional value is a key consideration as it directly impacts the overall health impact of consuming edible flowers.

Table 4. Criteria weights based on CRITIC method.

Criteria	Organoleptic properties	Antioxidant capacity	Nutritional value	Pigments	Biological values	Macro elements	Micro elements	Consumer preferences
Weight	0.175	0.163	0.146	0.141	0.106	0.102	0.099	0.067

Referring to Table 5, we use a combination of data from laboratory studies, a questionnaire survey, and an organoleptic evaluation by expert panels to construct the input matrix for multi-criteria decision models. According to the table's findings, 'Rainbows End' edible flower rose (with a nutritional value index of 8.91) and 'Hella' (with a score of 8.37) exhibited the highest nutritional value. Among the flowers studied, Hella' flowers (scoring 54.2) and 'Avalanche' (scoring 38) demonstrated the highest biological value.

The results of the organoleptic panel evaluation indicated that, from the evaluators' perspective 'Rainbows End' roses (three varieties), Dolce Vita rose, and Samurai rose received the highest sensory evaluations and regarding the presence of macro and micro-elements among the studied flowers 'Crimson Siluetta' and 'Samurai' roses garnered the most attention in both indexes.

Laboratory evaluation results concerning pigment measurements revealed that 'Hella' (with a score of 5.66) and 'Avalanche' (scoring 5.00) boasted the highest pigment content. Exploring diagnostic criteria as another facet of the input matrix for the decision-making model indicated that 'Crimson Siluetta' (scoring 85.83) and 'Rainbows End' (scoring 82.77) achieved the highest levels.

In a consumer survey involving 218 respondents 'Rainbows End' flowers emerged as the preferred choice for consumption, attaining an average score of 5.34. Following closely were 'Samurai' (scoring 5.14), and 'Dolce Vita' (scoring 5.12) in terms of consumer preference.

Table 5. Summary of criteria for each flower as input of decision matrix.

Cultivars	Nutritional value	Biological values	Organoleptic properties	Macro elements[a]	Microelements[b]	Pigments[c]	Antioxidant capacity (%)	Consumer preferences
'Hella'	8.370	54.152	5.017	2.857	1.17	5.667	80.277	4.683
'Crimson Siluetta'	7.067	20.806	5.200	4.000	2.67	3.667	85.833	5.001
'Rainbows End'	8.908	9.940	6.917	3.286	3.5	1.667	82.777	5.336
'Dolce Vita'	8.087	19.004	6.517	3.143	4.17	2.667	79.447	5.122
'Samurai'	6.819	16.760	5.433	4.000	4.0	2.333	79.720	5.144
'Avalanch'	7.486	38.024	4.950	3.714	5.5	5.000	78.613	4.769

[a, b, c] Mean rank from Table 1, Table 2 and Table 3.

In the first step of implementing multi-criteria decision-making, it is necessary to determine the weights assigned to the decision-making criteria. To achieve this, the opinions of six experts were considered for weight determination. According to the findings in Table 6, the critical analysis results highlighted that the organoleptic index, with a weight of Q = 0.175, carried the highest significance. Following closely, the antioxidant capacity criteria, with a weight of Q = 0.163, secured the second-highest position, while nutritional value, with a weight of Q = 0.146, emerged as a paramount indicator in the evaluation of selected cut roses.

Additionally, the consumer preferences index, with a weight of Q = 0.067, and micro-elements, with a weight of Q = 0.099, were identified as the least crucial criteria for choosing edible cut roses from the perspective of research experts.

After assigning weights to the criteria, three multi-criteria decision-making methods - ARAS, WASPAS, and TOPSIS - were employed to rank edible cut roses based on the established criteria. The results of each method are outlined below.

According to the findings from the TOPSIS analysis, 'Hella' roses (C = 0.74) secured the top rank, followed by 'Avalanche' (C = 0.64) and Crimson Siluetta roses (C = 0.39). Additionally, 'Samurai' and 'Rainbows End' were identified as the final two priorities among the examined flowers, considering the established criteria. Following the initial processing of the decision matrix using the ARAS and WASPAS methods, the edible flowers under study were arranged in descending order based on their Q and K values. (Table 6)

According to the findings from the TOPSIS analysis, 'Hella' (C = 0.74) secured the top rank, followed by 'Avalanche' (C = 0.64) and 'Crimson Siluetta' (C = 0.39). Additionally, 'Samurai' and 'Rainbows End' were identified as the final two priorities among the examined flowers, considering the established criteria. Following the initial processing of the decision matrix using the ARAS and WASPAS methods, the edible flowers under study were arranged in descending order based on their Q and K values.

Table 6. Results of comparisons between ARAS, WASPAS and TOPSIS and final rank.

Cultivars	ARAS		WASPAS		TOPSIS		Mean rank	Final rank
	K	Rank	Q	Rank	C	Rank		
‘Hella’	0.88	1	0.86	1	0.74	1	1	1
‘Avalanche’	0.83	2	0.84	2	0.64	2	2	2
‘Crimson Siluetta’	0.76	3	0.79	3	0.39	3	3	3
‘Dolce Vita’	0.73	4	0.76	4	0.30	4	4	4
‘Samurai’	0.70	5	0.73	5	0.24	6	5.33	5
‘Rainbows End’	0.70	6	0.72	6	0.26	5	5.66	6

Discussion

Flowers hold a timeless significance in our culture, often celebrated in literature for their natural wonders and symbolic beauty. Beyond their decorative appeal, flowers possess nutritional properties and biological benefits, making them a culinary staple for centuries (Lu et al., 2016; Chen and Wei, 2017; Grzeszczuk et al., 2018; Stefaniak and Grzeszczuk, 2019).

In recent years, the increasing creativity in culinary practices and a heightened focus on the medicinal and health benefits of food ingredients have contributed to a rise in the use of edible flowers. These flowers are esteemed for their unique visual appeal, organoleptic properties, and richness in nutritional and bioactive compounds, leading to their growing popularity in a variety of food and beverage applications (Sood et al., 2024). Among the most notable edible flowers is the rose, which is widely recognized for its ability to enhance the aroma, flavor, and presentation of dishes. Its nutritional value and health benefits have been extensively studied and documented in numerous research publications (Sood et al., 2024; Hegde et al., 2022). Edible flowers, such as ‘Hella’, ‘Crimson Siluetta’, ‘Rainbows End’, ‘Dolce Vita’, ‘Samurai’, and ‘Avalanche’ roses, find application in human nutrition. These flowers, with their distinct properties, play a role in various culinary processes and food decoration. Roses, including cultivars like ‘Hella’, ‘Crimson Siluetta’, ‘Rainbows End’, ‘Dolce Vita’, ‘Samurai’, and ‘Avalanche’, are commonly included in the human food basket to enhance the visual appeal of dishes. Notably, edible flowers, including roses, hold considerable nutritional and biological value (Rop et al., 2012). Edible flowers, including roses, offer vital nutrients like vitamins, minerals, and fiber. These flowers are rich in macro elements such as calcium, potassium, and phosphorus (Rop et al., 2012; Grzeszczuk et al., 2018; Pinedo-Espinoza et al., 2020), essential for supporting bone health, muscle function, and maintaining the body’s electrolyte balance. Furthermore, they provide microelements like iron, zinc, copper, and manganese in their nutritional composition (Navarro-Gonzalez et al., 2015). Edible flowers boast an important characteristic – antioxidant capacity. Packed with phytochemical compounds like flavonoids, they function as antioxidants, shielding against biological oxidation and damage from free radicals. The pigment content in these flowers is equally crucial, providing vibrancy and attractiveness to foods while carrying antioxidant properties. Different flower colors signify varying compounds, each with distinct antioxidant qualities.

Flower color, as the primary attribute perceived by consumers, plays a critical role in the acceptance and marketability of edible flowers. This impact is twofold: 1) it is associated with medicinal and nutritional value (health benefits) and 2) it enhances the cosmetic presentation of food (Nicknezhad et al., 2023). Considering both the visual appeal and the nutritional value of edible flowers, such as roses, these products offer a unique combination of aesthetic and sensory appeal, along with health benefits for consumers (Sood et al., 2024), as demonstrated in the present study. Favorable sensory characteristics are essential for achieving consumer acceptance. The compounds responsible for taste in various species of edible flowers differ, with bioactive compounds generally influencing the sensory properties of these plants. When evaluating the sensory aspects of edible flowers, criteria such as taste, smell, consistency, and appearance come into play. These factors help assess whether the flowers are both edible and desirable (Chetia et al., 2024). Nicknezhad et al. (2023) identified appearance, aroma, taste, and texture as key attributes that consumers use to evaluate the quality and attractiveness of edible flowers. Ultimately, the choice to incorporate edible flowers into one’s diet hinges on individual experience, taste preferences, and personal needs. Some may favor using flowers for their decorative appeal and pleasant taste, while others may abstain due to health concerns or unfamiliarity with the properties and benefits of edible flowers. Various rose cultivars are typically distinguished by differences in petal color. Flower color is closely linked to the nutritional, biochemical, and bioactive properties of roses, with different species exhibiting varying levels of nutritional, medicinal, and biological value (Mallick et al., 2024). Color is one of the most fundamental and influential sensory attributes when selecting new foods, particularly edible flowers. Even if a product is appealing in terms of taste and aroma, its color and visual quality play a crucial role in consumer preference (Nicknezhad et al., 2023; Duggirala et al., 2024).

The ‘Hella’ edible flower stands out as a popular and visually appealing choice with notable nutritional value. Renowned for its high pigmentation, Hella enhances the beauty of foods, aligning with research by Kinupp and Lorenzi (2014). Characterized by its white hue, this flower is commonly used to adorn various dishes, especially desserts and cakes. The pigments in the white nasturtium flower also contribute antioxidant properties, promoting overall health.

Furthermore, ‘Hella’ has a high biological value, reflecting its efficient digestion and absorption of essential nutrients by the body. Rich in vitamins and minerals, this flower supports immune system function and overall health. Incorporating the ‘Hella’ flower into cooking and food decoration not only enhances visual appeal but also enriches the nutritional profile of food, boosts antioxidant levels, and promotes overall well-being. ‘Rainbow End’ edible flower is valued for its significant food attributes, making it a popular choice for both cooking and decoration. Its noteworthy antioxidant capacity contributes to overall health by safeguarding against the impact of free radicals. Additionally, the flower possesses distinctive sensory properties that appeal to taste testers, making it a desirable option in culinary applications. Considering the widespread consumer preference for this flower, prioritizing sensory qualities becomes crucial for broader acceptance. This aligns with the findings of Purohit et al. (2022) and Nicknezhad et al. (2023) and emphasizing the importance of meeting sensory preferences for edible flowers to gain widespread consumer approval.

The Samurai rose, rich in both micro and macro elements, stands out as an optimal choice for culinary use and food decoration. Its exceptional nutritional profile, combined with unique sensory properties, makes it a preferred option. Incorporating this flower into dishes not only enhances nutritional value but also elevates visual and taste experiences. Contrary to common perception, flowers offer more than just decoration; they provide a distinctive blend of sensory delight and contribute to the nutritional content of food, as supported by research by Takahashi et al. (2021) and Nicknezhad et al. (2023).

Furthermore, the edible ‘Dolce Vita’’ Dutch rose, beyond its attractive appearance, offers valuable properties. Packed with nutritional benefits and a distinct taste, this rose adds diversity to the diet and contributes essential nutrients. The ‘Dolce Vita’ rose may contain antioxidants that combat stress and free radical damage, along with providing essential fiber for gut health, blood sugar control, and weight management. Additionally, it can offer vital vitamins like vitamin C, crucial for a robust immune system, healthy skin, and improved iron absorption. Consumption preferences for the ‘Dolce Vita’ Dutch rose, in its edible form, are subjective and depend on individual experiences and tastes. Fresh rose petals can be incorporated into salads, desserts, and drinks, or used as food garnishes based on personal preference.

The ‘Avalanche’ flower, available in a spectrum of red, orange, yellow, and pink to purple colors, offers a cool and sweet taste that can subtly alter the flavor of food. This edible flower, highlighted in the research by Guiné et al. (2020), proves versatile for enhancing the visual appeal of salads, desserts, drinks, and various dishes, aligning with the findings of Niknejad et al. (2023). The flower boasts pigments like anthocyanin, contributing both to its vibrant colors and nutritional content. With valuable nutrients and a high biological value, the ‘Avalanche’ flower serves as a wholesome addition to culinary endeavors.

The ‘Crimson Siluetta’ edible flower, or miniature rose, stands out not only for its beauty but also as a modest source of nutrients and antioxidants. Given that one of the primary objectives of using bioactive compounds from natural and plant sources is to harness their antioxidant properties and neutralize free radicals (Mallick et al., 2024), the ‘Crimson Siluetta’ rose offers significant appeal to consumers, both for its aesthetic beauty and its antioxidant and health benefits. Its notable antioxidant capacity protects against stress and damage from free radicals. While miniature roses offer limited nutritional content, they do contain essential nutrients like potassium, calcium, magnesium, and phosphorus in small amounts. Fresh petals can be incorporated into salads, desserts, or refreshing drinks like flower tea to maximize their benefits. Additionally, some commercial food and beverage products may utilize rose extract or spirit. In conclusion, the edible miniature rose flower, with its high antioxidant capacity and the presence of macro and micronutrients, proves to be an appealing choice for diversifying the diet and adding valuable nutrients to meal plans. Today, there is a growing demand for foods that are not only attractive and beautiful but also natural, healthy, and of high quality.

In essence, flowers bring together a distinctive blend of visual charm and nutritional advantages, rendering them a valuable component in the culinary realm. Appreciation for both the appearance and taste of flowers, coupled with an understanding of their role in promoting health, can facilitate the seamless integration of edible flowers into one’s diet (Kumari et al., 2021). As a result, the ultimate assessment of edible flowers, including roses and their diverse cultivars, hinges on factors such as nutritional value, antioxidant and pigment content, sensory properties, and individual preferences. Before incorporating any edible flower, gathering sufficient information about its origin is crucial, enabling informed decisions based on specific needs and relevant factors.

Conclusions

The study results indicate that the ‘Hella’ and ‘Avalanche’ rose varieties are the most suitable for edible applications based on eight specific criteria. Additionally, the ‘Rainbow End’ flower was found to possess the highest nutritional value, while the ‘Avalanche’ flower exhibited the greatest biological value among the edible flowers studied. However, despite these findings suggesting that these flowers can serve as a viable food source, a panel of experts did not favor them particularly in terms of taste and organoleptic properties. The organoleptic test data revealed that the ‘Rainbow End’ and ‘Dolce Vita’ rose varieties displayed acceptable flavors. Therefore, it is recommended to enhance their taste by incorporating approved food additives. In general, edible roses (grown in green spaces) held a significant advantage over cut roses. This is likely because green space roses are cultivated outdoors rather than in greenhouses, giving them a notable edge in chemical and biochemical composition compared to hybrid greenhouse roses. Additionally, given their lower cost and wider availability in Iran, edible roses are a more economical choice for culinary use.

In terms of macro and microelements, the ‘Samurai’ and ‘Crimson Siluetta’ flowers contained the highest levels of these elements. Among the examined flowers, the ‘Hella’ variety demonstrated the highest pigmentation, while the crimson variety had the highest antioxidant content. Considering all the properties and nutrients of the studied flowers, the ‘Rainbow End’ emerged as the most preferred choice among consumers.

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Author Contribution

FP: Data Curation, Writing – Original Draft, Resources. **DH:** Conceptualization, Investigation, Project Administration, Writing – Original Draft, Supervision. **MSA:** Conceptualization, Data Curation, Methodology, Formal Analysis, Writing – Original Draft, Writing – Review & Editing

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Data will be made available upon request to the authors.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGpt 4 to proofread. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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