Research paper

Sensory stability of pistachio nut (*Pistacia vera* L.) varieties during storage using descriptive analysis combined with chemometrics

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**ABSTRACT**

Sensory evaluation involves the measurement and examination of the sensory properties of foods. This paper deals with the use of some chemometrics techniques for sensory recognition and stability of four Iranian pistachio nut varieties (Kale-Ghouchi, Akbari, Ohadi, and Momtaz) during storage. For this purpose, nine sensory attributes (bitterness, firmness, sweetness, rancidity, crunchiness, salty, sour, glossy, roasted) were evaluated by a professional trained human sensory panel to examine the changes during 8 months of storage. Several chemometrics techniques were employed for this aim. Linear techniques such as principal component analysis (PCA) and Linear Discriminant Analysis (LDA) were performed over the data that partial overlapping were seen for all treatments of pistachio nut varieties. Moreover, artificial neural networks such as Probabilistic Neural Networks (PNN) with Radial Basis Functions (RBF) and FeedForward Networks with Backpropagation (BP) learning method were then used. The methods have proved a good capability to recognize and classify the stored pistachio nuts satisfactorily in such a way, for whole varieties, high classification accuracies were obtained. The highest success rate was found for Kale–Ghouchi variety (D) as 100%. It was revealed the classification accuracies were better using BP compared with PNN. The achievements of this study can be of great interest to pistachio nut producers for the management of storage length and more particularly export circumstances. The results obtained can be used as a reference data for electronic nose and electronic tongue experiments in future studies.

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1. Introduction

Pistachio nut (*Pistacia vera* L.) is known as one of the well-known tree nuts. Only the fruits of *P. vera* get a large enough size and are acceptable to consumers as edible nuts whereas several species of the genus *Pistacia* are referred to as pistachio (*Shokraii and Esen, 1988*). Pistachio nuts are mostly produced in Iran, Turkey, and the USA. Based on FAO statistics (*Food and Agriculture Organization, 2013*), Iran has a significant contribution to pistachio nut production in the world. Thus, pistachio nut has a grand marketing value for Iran so that more than 50 pistachio varieties are cultivated in various areas of Iran such as Feizabad, Rafsanjan, Kerman, etc.

Storage of pistachio nut and its management is a challenging issue among postharvest tasks because the quality of stored pistachio nut and sensory descriptors in particular depends on the storage length, storage conditions and variety type. Storage circumstances affect on the consumer preferences and marketing value accordingly. People tend to consume the product with high quality and safety, and low cost, consequently this attitude obliges food engineers to look for product quality control throughout the process (*Cho et al., 2010; Etaio et al., 2010; Adelkhani et al., 2013*).

Sensory evaluation ensures the product quality resulting in optimum cost, less waste, and eventually success in a competitive space (*Parr et al., 2010*). Therefore, an awareness of sensory changes of stored pistachio nut could be helpful for the monitoring and managing the strategies of handling and storage of this product.

Descriptive analysis is one of the key kinds of methodology for sensory analysis. It is frequently employed in the industry for product improvement and quality control. Rating scores are considered in the descriptive analysis. As the definition implies, sensory evaluation encompasses the measurement and study of the sensory properties of foods and other materials. Analysis of the panelist reactions and its interpretation is also included in sensory evaluation. Such evaluation is needed to examine and anticipate the impacts of product changes in the marketplace (*Haseleu et al., 2009; Yin and Ding, 2009*).
Some research works on sensory evaluation of pistachio nut have been reported earlier (Kader et al., 1982; Palazoglu and Balaban, 1998; Kashani Nejad et al., 2002; Bellomo and Fallico, 2007; Tavakolipour and Kalbasi Ashtari, 2008; Nepote and Kontominas, 2009; Bellomo et al., 2009; Sedaghat, 2010; Tsantili et al., 2010; Tavakolipour et al., 2010; Penci et al., 2013; Arena, Ballistreri and Fallico, 2013; Tavakolipour, 2013). To date, there exist no documents reporting the computerized sensory measurement and recognition of pistachio nut during storage. Therefore, the target of this study was to use sensory data coupled with computational tools for the recognition of stored pistachio nuts. For this purpose, four commercial pistachio varieties are considered and artificial neural network (ANN) is used to find sensory stability of the nuts in storage conditions.

2. Materials and methods

2.1. Samples

Four pistachio nut varieties were selected including Kaleb-Ghouchi (D), Akbari (W1), Ohadi (W2) and Momtaz (W3), the major commercial varieties in Iran. The samples were obtained from Feizabad (a region located on the north east part of Iran at latitude: 35° 01′ N and longitude: 58° 78′ E). After harvest, the pistachio nuts were immediately transported. After initial processing (dehulling, blank separation, unpeeled pistachios separation, washing and sorting), the samples were dried at the identical circumstances. Sun drying method was considered in such a way a thin layer of the samples were placed on a concrete surface under the sun for one day and the average drying temperature was found to be around 28 ℃. After drying, 2 kg samples were taken and put into the sealed plastic bags and stored at 0 ℃ and quality descriptors were then examined (Kader et al., 1982; Kashani Nejad et al., 2002). On top of the bags, a small hole was punched for allowing the panelists to transfer the samples into their mouths without observation. The interval of 1 month up to 8 months was considered for the evaluation. Samples were located at room temperature for 12 h before evaluation to attain the ambient temperature.

2.2. Trained panel descriptive sensory analysis

The sensory test was carried out by 20 panelists (10 males and 10 females). All panelists had prior experience on sensory evaluation of pistachio nuts. The training of the panel was accomplished for three sessions. During the 2 h sessions, a group discussion was held with the panelists for the development of a harmony vocabulary for the sensory attributes of pistachio nuts and to recognize references in order to remind panelists for quality attributes. To evaluate panel performance, a traditional profile was performed with the pistachio nut samples. Assessors examined the attributes present in the list by scoring their intensity in a line scale (0–10) where 0 to 10 signified poor to excellent. The scores were calculated by measuring the line length from the beginning (weak) to the panelist’s mark. Definitions and related terms of the attributes were agreed in previous round table sessions.

Several indicators of taste, appearance, and aromatic were evaluated in this study (Kader et al., 1982; Nepote et al., 2009; Martínez et al., 2011; Penci et al., 2013). The quality attributes and their descriptions were: a) bitterness: taste on the tongue related to bitter solutions like caffeine, b) firmness: a force required for compressing a sample between molar teeth, c) sweetness: taste on the tongue relevant to sucrose solutions, d) rancidity: an objectionable taste distinguished by oxidized oil; e) crunchiness: force required and quantity of sound created from chewing a sample with molar teeth, f) salty: taste on the tongue relevant to the sodium chloride solutions, g) sour: taste on the tongue related to acid agents for instance citric acid solutions, h) glossy: the appearance related to the amount of light which is reflected by the surface of product, i) roasted: the aroma related to medium-roasted pistachio.

2.3. Data analysis

Several chemometrics tools were employed to analyze the data gained. Chemometrics is defined the use of multivariate techniques based on describing multiple parameters in a complex system in order to extract sufficient and useful information about the studied system using multivariate methods. The motivation for use of chemometrics is the capability of simple objective measurement combined with multivariate techniques for the replacement of expensive sensory evaluations. Matlab v7.6 (The Mathworks Inc., Natick, MA, USA) was used for data analysis in this study.

There exist a large number of approaches for data classification. Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) as two widely used techniques for dimensionality reduction of data were employed (Ghasemi-Varnamkhasti et al., 2012a,b). The mean ratings of the four stored pistachio nut varieties for nine specified attributes were then analyzed by PCA. This technique was considered to reduce the dimensionality or in other words the number of variables of the dataset while most of information present in dataset is retained (Duda et al., 2001). PCA results were then confirmed with more powerful chemometrics tools like Probabilistic Neural Networks (PNN) with radial basis function. Finally confusion matrices to show success rates of classification are encompassed. An algorithm for LDA was employed in order to achieve better classification in comparison with Principal Components Analysis. PCA is a clustering method, while LDA is a classification method. In addition, in PCA, the shape and location of the datasets alter by transforming to another space while in LDA, location does not change but more class discrimination is provided among the given classes. Moreover, distribution of the features is better recognized (Otto, 2007; Zhao et al., 2010).

In this study, a probabilistic neural network (PNN) was used for classification purposes as well. The architecture of PNN is depicted in Fig. 1. This network encompasses three layers: the input layer: with three neurons which correspond to three principal components; the hidden layer: radial basis transfer functions, and a competitive layer in the output. Leave one out cross validation was addressed to check the network performance. Leave one out includes training n different nets (i.e. number of measurements) by use of n – 1 training vectors; whereas the validation of the trained

Fig. 1. Architecture of a probabilistic neural network (PNN).
net was carried out regarding the remaining vector. This process would be done $n$ times till all vectors are validated (Dutta et al., 2010; Hsieh and Chen, 2009; Specht, 1990). Also, a back-propagation (BP) network was outlined including three layers: the input layer with three neurons which correspond to the first three components, a variable number of neurons in hidden layer, output layer with nine neurons related to the pistachio nut classes. The network takes into account the inputs and then examines its outputs in comparison to the desired outputs. Subsequently, errors were found and were then propagated back via the system for adjusting the weights to control the outputs of the network. This procedure occurs many times until the errors are diminished. It is worth mentioning the same set of data is processed many times when network training as the connection weights are always refined (Bishop, 1999; Chen et al., 2010). Performing the procedures, classification accuracy was then computed for each method and confusion matrices are then presented.

3. Results and discussions

PCA results are illustrated in Fig. 2 in which storage classes of pistachio nuts are demonstrated. For instance, D1 is designated to fresh pistachio nut just before storage; D2 corresponds to the product after 1 month from the storage date and accordingly other labels (W1, W2, and W3) are illustrated. The first two principal components explain the maximum quantity of variance in the original dataset. The components related to the large variation in the data are known as the new axis to achieve the plots of the pistachio classes called as score plot. The PCA score plots of PC1–PC2 account for 66%, 56%, 53% and 55% of variance for D, W1, W2 and W3, respectively (Fig. 2). The first class seen in the left side of the score plot is relevant to the fresh class in such a way identification power of D1 and W3-1 (fresh pistachio nuts of D and W3) from other classes (shown in Fig. 2a & c) is lesser than that of W2-1 and W3-1 (fresh pistachio nuts concerning W2 and W3) as illustrated in Fig. 2b and d, respectively. A clearly distinguish is found for early months of storage of D and W2 whereas the groups related to lately months of storage are partially overlapped (Fig. 2a and c). This observation is different for W3 in which the classes are overlapped in early months of storage. This observation shows unlike storing the pistachio varieties at the same conditions but the changes of sensory attributes for each variety are different in storage process that confirms the important role of unique chemical interactions related to each variety on nut quality as pointed out in the literature by Tsantili et al. (2010). They studied sensory differences in nuts among pistachios and then suggested that most

![Fig. 2. Score plots of the PCAs related to pistachio nut varieties of (a) D, (b) W1, (c) W2, (d) W3 (D1, W1-1, W2-1, and W3-1 correspond to fresh pistachio nuts and other labels are designated to the stored samples dated from storage time with the interval of 1 month).](image-url)
of the measured attributes were significantly affected by the variety. In addition, they concluded that the results show that these discrepancies would provide each variety most suitable to specified types of final product and more use. Previously, Kader et al. (1982) had reported that the pistachio nut varieties (Kerman, Red Aleppo, Trabonella and Bronte) showed differences among sensory quality indicators. Similar reports have been documented in the bibliography (Labavitch et al., 1982; Razavi et al., 2007; Kallsen et al., 2009).

As seen in Fig. 2d, the speed of sensory change in early months of the storage is lesser than that of in lately stages indicating the more stability in early storage months; even though in general, many factors like temperature affect for such sensory changes (Palazoglu and Balaban, 1998; Thompson, 2003). Usually, the temperature of postharvest storage is not considered to have an effect on the quality of pistachio nuts, probably, because of the short period of this stage in comparison to the long shelf-life of the pistachios. Therefore, it seems that storing the pistachio nuts in low degree of temperature would lead to more stability in early stages of W3. Arena, Ballistreri and Fallico (2013) studied the effect of storage temperature on the quality of pistachio nuts. They reported that in high storage temperatures, the free fatty acids content could increase and the peroxide value alters the quality indicators of the nuts and have a momentous influence on the triacylglycerols distributions. Moreover, the authors concluded that in hopes of avoiding lipid oxidation and to best preserving the nut quality, low storage temperatures should be recommended to storehouse managers. Similar report has been documented by Tavakolipour and Kalbasi Ashtari (2008) who suggested the storage temperature below 5°C for pistachio nuts.

Long storage period also has unsuitable influence on pistachio quality. Since the storage temperature in this study is very low, it seems that long storage has significant contribution for the changes in sensory attributes. This is in close agreement with the findings of Tavakolipour (2013) who reported longer storage times cause to accelerate the deteriorative reactions in pistachio nuts mainly on fat component. In another research effort, Bellomo et al. (2009) reported that oil stability in stored pistachio nut is merely affected by the length of storage.

LDA has been also used in the current study, like PCA, as a feature reduction way to determine a hyper plane with smaller dimension on which the points would be projected from higher dimension. Nonetheless, to keep maximal structure in the data in a lower dimension, PCA picks a certain direction but LDA considers a

Fig. 3. Score plots of stored pistachio nut: (a) D variety by LDA, (b) D variety by LDA without validation, (c) W1 variety by LDA,(d) W1 variety by LDA without validation, (e) W2 variety by LDA, (f) W2 variety by LDA without validation, (g) W3 variety by LDA, (h) W3 variety by LDA without validation (D1, W1-1, W2-1, and W3-1 correspond to fresh pistachio nuts and other labels are related to the stored samples dated from storage time).
direction to attain maximum separation among the groups studied. The results obtained by LDA proved a more appropriate classification compared to PCA results as illustrated in Fig. 3. In LDA method, the variance between pistachio nut groups as well as the variance within pistachio nut groups is maximized. Then a reasonable rule is found to discriminate between them by forming of the linear functions of the data in order to maximize the proportion of the between-groups sum of squares to the within-groups sum of squares. Hence, the linear functions would be orthogonal for the classification of an observation by calculation of its Euclidean distance from the class centroids. Thus, the observation is allocated to the closest class. In present study, the performance of this approach was evaluated in such a way the group centroids were estimated using a leave-one-out cross validation method. Without regard to the missing data points, the group centroids are found and each observation is omitted from the data set accordingly. Afterwards, the eliminated observation is classified taking into account these new class centroids. So, the data point is replaced and the next observation taken away from the data set accordingly. This process is stopped when all observations have been left out. Therefore, true classification percent of the observations would be found out comparing the correctly class membership with that estimated by LDA. This presents a suitable norm of the reliability of the classification method (Otto, 2007; Zhao et al., 2010).

Then, the PCA and LDA results were confirmed with the ANN studied. In the case of BP, during training, different number of neurons in the hidden layer was tried. Furthermore, some activation functions such as pureline, tansig and hard-limit were tested for the output layer. Better results were obtained by pureline activation function. At last, the classification success rates were found to be 100%, 89%, 89% and 87% for D, W1, W2, and W3, respectively. The confusion matrices are presented in Tables 1–4. The similar results were gained using PNN. The confusion matrices of whole pistachio nut varieties are illustrated in Tables 5–8. In total, among the methods used, Backpropagation (BP) showed the greatest accuracy for the characterization of stored pistachio nuts.

The speed of sensory changes for D variety was more than others. Therefore, the quality stability of D is not appropriate during storage. To rectify this problem, the pistachio nut producer can use some techniques to enhance the quality stability. Gamma irradiation can be an effective alternative technology in postharvest control of pistachio nut (Mexis and Kontominas, 2009).

In this research, the stability of different varieties of stored pistachio nut was addressed. Stability of sensory attributes is influenced by some chemical interactions in pistachio nut during storage period. An awareness of this issue is of crucial important for the management of storage conditions and to correctly preserve the sensory properties. It is well known that some ambient conditions
including oxygen level, light, and variable temperature can reduce quality attributes such as taste, flavor, color and nutritional components (Bellomo et al., 2009).

The results reported in this study can be coupled with biomimetic-based devices such as — electronic nose and electronic-tongue (Wei et al., 2009; Ghasemi-Varnamkhasti et al., 2010). Since sensory evaluation tests are time consuming and need expensive facilities, thus, electronic tongue and electronic nose as innovative analytical tools can be used instead of sensory evaluation. It is expected that the relating these results with e-tongue and e-nose to be successful.

Since challenging problems relevant to the sensory evaluation of pistachio nut and other food are well known, having the professional sensory panels is mandatory to ensure reproducibility of the results and this means expensive method. Fast saturation of the panelists during test is another challenge (Rudnitskaya et al., 2009). Therefore, sensory evaluation is a slow and expensive approach suffering from irreproducibility even with professional panels. Nowadays, noteworthy efforts are being done for the development of instrumental tools for regular analysis of taste attributes of foodstuffs and pistachio nut in particular. E-nose and e-tongue can be the options for this goal (Rudnitskaya et al., 2006; Lozano et al., 2007; Hayashi et al., 2008; Wei et al., 2009; Peres et al., 2009; Ghasemi-Varnamkhasti et al., 2010; Ghasemi-Varnamkhasti, 2011). The results obtained from the current study could be considered as a reference data in such systems so that there are many reports on the correlation of the output of electronic noses and tongues to sensory data. However, the perspectives for these types of instruments are very promising, and employment of such systems is expected. Correlating the data of this study with e-tongue and e-nose to be successful.

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### 4. Conclusions

The shelf life of four varieties of pistachio nuts (Kale-Ghouchi, Ahmadi, Ohadi, and Momtaz) during storage period were studied using sensory panelists combined with chemometric tools. The initial results did not show any significant difference among the data obtained. For this reason, advanced techniques of artificial neural networks (BP and PNN) were used and the stages of stored foodstuffs and pistachio nut in particular. E-nose and e-tongue can be the options for this goal (Rudnitskaya et al., 2006; Lozano et al., 2007; Hayashi et al., 2008; Wei et al., 2009; Peres et al., 2009; Ghasemi-Varnamkhasti et al., 2010; Ghasemi-Varnamkhasti, 2011). The results obtained from the current study could be considered as a reference data in such systems so that there are many reports on the correlation of the output of electronic noses and tongues to sensory data. However, the perspectives for these types of instruments are very promising, and employment of such systems is expected. Correlating the data of this study with e-tongue and e-nose to be successful.

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**References**


