Investigating the effect of sensory properties of black plum peel marmalade on consumers acceptance by Discriminant Analysis

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A B S T R A C T

One of the goals of producing and developing new products is to provide desirable features to the target community, followed by promoting marketability and gaining more market share in similar products basket. In this study, in order to investigate the effect of sensory characteristics of black plum marmalade on its acceptance, sample data with 180 observations and discriminant analysis method were used. The sensory properties that were evaluated in this product included color, flavor, firmness, adhesiveness and spreadability. Discriminant analysis classified 89% of observations correctly in the acceptance and non-acceptance classes. Accordingly, the characteristics of color, consistency, flavor, hardness and spreadability had a positive and significant effect on the acceptance of the product by the respondents and adhesiveness had a negative and significant effect on the acceptance of the product. Also, based on these results, the largest contribution in discriminating the acceptance and non-acceptance of this product is related to the spreadability, flavor and hardness, respectively. Therefore, in order to attract customers and market effectiveness, it is suggested to pay special attention to these characteristics in the production of black plum marmalade.

1. Introduction

Plum (prune) is a fruit from Rosacea family and Prunus genus and the origin of that is from the border of the Caspian Sea. Plums are consumed fresh or processed (Stacewicz-Sapuntzakis et al., 2001). Prune fruits have different color (yellow, red, and purple or black), flavor (from sour to sweet), shape (spherical or oval), size (6–10 cm), and ripening date (Lucka, 1994; Somogai, 2005). According to the FAO, Iran is one of the largest producer of prunes in the world by 313,103 tons in 2018 (FAO, 2020). It’s reported that more than 50,000 tons of plum peel was produced in Iran (Jihad Agriculture, 2020). Nutritionally, prune is a useful fruit and a rich source of carbohydrates, amino acids, vitamins, minerals, dietary fibers, and phenolic compounds (Donovan et al., 1998; Jones and Bullis, 1929; Kimura et al., 2008; Siddiq, 2006). It is a fruit with antioxidant, anticancer, antihyperglycemic, anti-hyperlipidemic, antihypertensive, anti-osteoporosis, and laxative activities (Jabeen and Aslam, 2011).

During the plum drying process, a considerable amount of plum peel remains. Moisture content, bulk of this material and its spoilage can pollute the environment. Although, it contains valuable compounds and it can be used to produce high value products (Mohammadi-Moghaddam et al., 2020a). Black plum peel marmalade is a semisolid food and it’s made of black plum peel, water, sugar, citric acid, and pectin. This food can be used for breakfast or in cookies, cakes and chocolates as confectionary products. There are a number of published researches about the usage of chemometric methods for classification of fruit products (Powers and Keith, 1968; Jahanbakhshi and Kheiralipour, 2020; Lashgari and Mohammadigol, 2016; Hidalgo et al., 2018; Zimmer and Schneider, 2019; Abad-García et al., 2012; Mitic et al., 2014; Zielinski et al., 2014; Gliszczynska-Świglo et al., 2018; Mohammadi-Moghaddam et al., 2020b; Moghaddam et al., 2016; Estaji et al., 2020). Our studies showed that, no published literature was found on the usage of Discriminant Analysis (DA) for classification of semisolid foods like jam and marmalade. So, the objectives of this study were to (1) usage of Discriminant Analysis to divide the black plum peel marmalade into acceptable and unacceptable categories (2) study the effect of pectin and black plum peel concentrations on the acceptance of samples (3) Identify the effect of each sensory parameter on the acceptance of marmalade.

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2. Materials and methods

2.1. Marmalade preparation

Raw materials of marmalade production were frozen black plum peels, pectin, sugar, and citric acid. Plum peels were accumulated from plum processing manufactories, Neyshabur, Iran, pectin (Green Ribbon, Citrus, 57–62% degree esterification, NATUREX, Switzerland), citric acid (Jovein, Sabzevar, Iran) and sugar from supermarkets, Neyshabour, Khorasan Razavi, Iran.

The black plum peels were washed, squeezed, frosted, and accumulated in a freezer (−18 °C) until production. The defrosted plum peels were mixed with water and homogenized (Sunwood food processor, Italy). Therefore, the mixture was filtered in order to get the puree. To produce marmalade, sugar syrup was firstly prepared (70% Brix and citric acid were added and the heating process was continued to 65–70 °Brix and pH = 2.8 to 3.5. The marmalade samples were cooled and filled in glass dishes and cumulated at room temperature (25 °C ± 2) for at least 24 h. The ingredients of marmalade were plum puree (40, 50 and 60%), and pectin (0.3, 0.4, 0.5, and 0.6%). Table 1 shows different formulations of black plum peal marmalade.

![Table 1](https://example.com/table1.png)
where \( \bar{y}_1 \) and \( \bar{y}_2 \) are the mean of discriminatory variables in the first and second groups, respectively, and \( x \) and \( S \) are the mean of the variables and variance of observations in the two groups, respectively. The intergroup variance is also equal to \( \lambda S^2 \) and the intragroup variance is \( S^2 \) (Maddala, 1983). \( \lambda \) should be selected so that the following statement (equation (5)) is maximized:

\[
\Phi = \frac{\lambda}{\lambda S^2} (\bar{y}_1 - \bar{y}_2)^2 \tag{5}
\]

By deriving equation (5) from \( \lambda \) and equating it to zero, the value of \( \lambda \) is obtained equation (6):

\[
\hat{\lambda} = S^{-1} (\bar{y}_1 - \bar{y}_2) \tag{6}
\]

By calculating the coefficients of discriminatory variables, the average of the Discriminant function for the two groups can be obtained, which is equal to equations 7–8:

\[
\bar{y}_1 = \lambda \bar{y}_1 = (\bar{y}_1 - \bar{y}_2) S^{-1} \bar{y}_1 \tag{7}
\]

\[
\bar{y}_2 = \lambda \bar{y}_2 = (\bar{y}_1 - \bar{y}_2) S^{-1} \bar{y}_2 \tag{8}
\]

To attribute a new observation to the Discriminant vector \( x_0 \), the value of the Discriminant function \( y_0 \) is calculated using the discriminant coefficients obtained equation (9):

\[
\hat{y}_0 = \lambda \hat{y}_0 = (\bar{y}_1 - \bar{y}_2) S^{-1} x_0 \tag{9}
\]

If \( y \) is closer to \( y_1 \), the new observation will belong to the first group, and if it is closer to \( y_2 \), it will belong to the second group. In fact, \( y_0 \) is closer to \( y_1 \) when, assuming \( \bar{y}_1 > \bar{y}_2 \), the equation (10) is established:

\[
y_0 > \frac{1}{2} (\bar{y}_1 + \bar{y}_2) \text{ or } |y_0 - \bar{y}_1| > |y_0 - \bar{y}_2| \tag{10}
\]

Inequality 10 is used when the number of observations in two groups is equal. Otherwise the equation (11) is used:

\[
y_0 = \frac{1}{n_1 + n_2} (n_1 y_1 + n_2 y_2) \tag{11}
\]

where \( n_1 \) and \( n_2 \) are the number of observations in the first and second groups, respectively.

To perform the classification using Discriminant Analysis, a new observation must be attributed to one of the two groups using a criterion. Cut-off value is one of the criteria used for this case. To calculate this criterion, at first, using the estimated coefficients of the Discriminant function, the value of the Discriminant score is obtained for all observations. Then, if the number of observations in the two groups is not equal, the equation (12) is used to calculate the mean value (Sharma, 1996).

\[
\text{Meanvalue} = \frac{n_0 Z_0 + n_1 Z_1}{n_0 + n_1} \tag{12}
\]

where \( Z_0 \) and \( Z_1 \) are the average of the Discriminant score for the two groups, respectively, and \( n_0 \) and \( n_1 \) are the number of group members, respectively. If the value of the Discriminant score for the new observation is greater than or equal to the median value, the new observation belongs to the first group and otherwise to the second group.

To analyze this method, it is necessary to examine the differences between groups by univariate statistical test. The U or Wilks Lambda statistic is used to make a decision the equality of means. This statistic expresses the significance of a variable when compared individually between two groups and is equal to the ratio of the sum of the squares within the group to the sum of the total squares for each variable (Grimm and Yarnold, 1995). When the means are equal in the two groups, the Wilkes-Lambda statistic equals one. In other words, larger values of the statistics did not indicate a significant difference between the means within the groups, while smaller values showed that the means of the groups were different (Huberty and Olejnik, 2006). In the pattern of differentiation of standardized and non-standardized coefficients, in fact, the coefficients of the variables when expressed in terms of initial values; and standardized coefficients are used when the variables are standardized with a mean of zero and a standard deviation of one criterion. Since the values of the coefficients of the Discriminant function do not provide any indicators to express the relative importance of the variables with differences in the two groups, to achieve this goal, the correlation between the Discriminant function and the values of the variables is used. The structure matrix is presented. In other words, the values of the structure matrix or correlation coefficients reflect the amount of variance explained by each of the independent variables regarding the Discriminant function.

### 3. Results and discussion

Sensory properties of foods is very important and it can be affected by many factors such as type of foods, the environmental conditions and consumers that use the foods. The acceptability of foods is very important because it is an enjoyment for people from eating food and pleasure of food is perceive from the cradle to the grave (Bourne, 2002). For semisolid foods, acceptability is determined by food sensory attributes including color, flavor, texture, appearance and packaging. Acceptability of foods can be influenced by the sensory properties of the food, outlook of consumer, culture, physiological status like hunger, thirst, illness and other features (Murray and Baxter, 2003; Joyner, 2019; Costell et al., 2010). Table 2 shows the results of the group means equality test for each variable. As can be seen, the sensory parameters of black plum peel marmalade are significantly different from each other (\( \rho < 0.01 \)). In order to achieve the degree of participation of each variable in the Discriminant function, the coefficients of this function were examined. Table 3 shows the results of standardized and non-

### Table 2

| Variables | Wilk’s Lambda | F  |
|-----------|---------------|----|
| Color     | 0.689         | 69.093***|
| Consistency| 0.847         | 27.670***|
| Flavor    | 0.571         | 114.969***|
| Firmness  | 0.613         | 96.462***|
| Adhesiveness | 0.617     | 95.026|
| Spreadability | 0.481     | 165.038***|

***Significance at 0.01

### Table 3

| Variables        | Standardized coefficient | Non-standardized coefficient |
|------------------|--------------------------|-------------------------------|
| Color            | 0.137                    | 0.082                        |
| Consistency      | 0.200                    | 0.058                        |
| Flavor           | 0.369                    | 0.216                        |
| Firmness         | 0.256                    | 0.190                        |
| Adhesiveness     | -0.157                   | -0.110                       |
| Spreadability    | 0.639                    | 0.381                        |
| Constant         |                          | -5.275                       |
standardized Discriminant function coefficients. Standardized coefficients show that the adhesiveness of the samples has a negative effect and the color, flavor, consistency, firmness and spreadability have positive effects on the total acceptance of the samples. Non-standardized coefficients are the values of the coefficients of the detection equation or distinguishing between acceptable and unacceptable samples, and the magnitude of these coefficients indicates the change in the degree of discrimination due to the change of a unit of independent variables. Based on this, it can be expected that the spreadability increases the Discriminant score by 0.381 units (Table 3). In other words, by assuming other conditions to be constant, having a good spreadability can increase the quality of the product and its acceptance probability. Based on this result, it seems that, the ability to move and place the marmalade on the bread is of great importance from the point of view of the panelists. According to the results of Table 4, with falling one unit of color, consistency, flavor and firmness, the Discriminant score increases by 0.082, 0.058, 0.216 and 0.190 units, respectively, and with increasing adhesiveness, the Discriminant score reduces by 0.110 units. These results are consistent with our consequences in ANOVA test. According to ANOVA test, increasing the black plum peel puree reduced the flavor, color, spreadability, adhesiveness, and total acceptance scores. The increase of pectin led to a decrease in spreadability and color scores. According to the panelists, the sample with 50% black plum peel puree and 0.4% pectin had the highest acceptability (Estaji et al., 2020). Based on these two statistical methods, it can be said that the lower the amount of pectin and black plum peel puree concentrations, the higher the quality and acceptance of marmalade samples.

The values of the coefficients of the Discriminant function do not provide any indicators to express the relative importance of the variables with differences in the two groups. To achieve this goal, the structure matrix is used. Table 4 shows the values of structure matrix. According to Table 4, by comparing the structure matrix, it can be said that color, consistency, flavor and firmness have the largest structural coefficient and they have the greatest contribution in discriminating between marmalade samples. While adhesiveness and spreadability have the lowest structural coefficient and therefore has the lowest contribution in discriminating between marmalade samples. Adhesiveness and spreadability have the lowest structural coefficient and therefore has the lowest contribution in discriminating between marmalade samples. According to Table 4, the canonical coefficient is equal to 0.786. This value indicates that there is a good correlation between the independent variables and the Discriminant score. The greater the degree of this correlation, the greater the ability of the model to discriminate between individuals in groups.

In addition to the values that show the degree of participation of each variable in the Discriminant pattern, the significance of the whole Discriminant function can also be examined in terms of the overall fit of the information. Significant test results based on Chi-square criteria are given in Table 5. As can be seen, it is 144.330, which is significant at the level of 0.01%, which means that the average of all Discriminant variables in the two groups are completely different at the same time, and the two groups can be distinguished using these variables.

### Table 4
Correlation between common groups between Discriminant variables and Discriminant function.

| Variables       | Structure matrix values |
|-----------------|-------------------------|
| Color           | 0.817                   |
| Consistency     | 0.682                   |
| Flavor          | 0.624                   |
| Firmness        | 0.620                   |
| Adhesiveness    | 0.528                   |
| Spreadability   | 0.334                   |
| Canonical correlation coefficient | 0.786 |

Table 5
The results of significant test of Discriminant Analysis model.

| Test of function (s) | Wilk’s Lambda | Chi-square | df | Sig. |
|----------------------|---------------|------------|----|------|
| 1                    | 0.382         | 144.330    | 6  | 0.000|

Table 6
Classification of marmalade samples into accepted and non-accepted samples.

| Main observations | Number of observations | Predictive results |
|-------------------|------------------------|--------------------|
| Acceptance        | 94                     | 88                 |
| Rejection         | 61                     | 11                 | Percentage of correctly classified observations of the total observations |
|                   |                        | 6                  |
|                   |                        | 50                 |
|                   |                        | 89                 |

The results of Table 6 show that the estimated Discriminant Analysis model from 94 observations of the first group (acceptance group), 88 observations (93.62%) correctly placed in the accepted group. However, 6 observations (6.38%) were incorrectly placed in the second group (non-acceptance group). Also, out of 61 observations of the second group (non-acceptance samples), 50 cases (81.97%) were correctly classified in this group and 11 (18.03%) observations were incorrectly placed in the acceptance group. In this analysis, the accuracy of prediction is 89%. In other words, it can be said that the Discriminant Analysis model estimated with the above-mentioned characteristics is able to predict the group of marmalade samples based on the different amount of plum peel puree and their pectin.

### 4. Conclusion

The results of Discriminant Analysis showed that spreadability and adhesiveness have important effect on the total acceptance of marmalade samples. Increasing the spreadability enhanced the Discriminant Analysis score while increasing the adhesiveness reduced the Discriminant Analysis score. Although increasing the color, consistency, flavor, and firmness also increased the Discriminant Analysis score, the increase in spreadability had the greatest effect on the score. According to the results of structure matrix, spreadability, flavor, firmness, adhesiveness and color had the largest structural coefficient and the greatest contribution in differentiating between marmalade samples, while consistency had the lowest in differentiating between products. The Discriminant Analysis model was able to predict the samples based on the amount of pectin and black plum peel puree (the prediction percentage of the samples was 89%). Therefore, using the results obtained from the above Discriminant Analysis model and placing variables in the framework of this model, it is possible to determine to a large extent in which group the produced sample will be placed so that an appropriate and acceptable formula can be determined before the production of the product. By recognizing the characteristics preferred by consumers, a formulation can be prepared and presented that has the highest acceptance among consumers, and in this way, with the lowest cost, the highest consumer satisfaction and income for the producer is achieved.

### Declaration of Competing Interest

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.
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