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Multidimensional Investigation of the Effect of Pre-treatment Solutions on Drying Characteristics and Raisin Quality

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ABSTRACT

This study aims to evaluate the relationships between pre-treatment solution, variety, drying characteristics, and raisin quality in raisin production, using multivariate analysis methods. The study was conducted on raisins obtained by dipping Bineteti and Zeyti local seed grape varieties in 13 different pre-treatment solutions which were obtained by mixing potassium carbonate and sodium bicarbonate with olive oil, hazelnut oil, and sesame oil at different concentrations. The dipped grapes were dried in the sun on a concrete drying platform. In the study, data of 15 numerical variables related to drying characteristics and raisin quality were reduced to four principal components (PC1, PC2, PC3 and PC4) using the principal component analysis (PCA), and their score values were numerically obtained. Then, two grape varieties, 13 pre-treatment solutions, and the four principal components were analyzed by non-linear principal component analysis (NLPCA). In addition, a cluster analysis was performed to determine the prominent pre-treatment solutions in terms of drying characteristics and raisin quality. It was determined that the pre-treatment solutions were effective on L^*, a^*, b^*, chroma (C^*), hue (h°), a/b values, antioxidant activity, total phenolic content, and drying time constituting PC1. It was remarkable that the colour parameters in prominent clusters in the cluster analysis also form PC1 in PCA analysis. The best pre-treatment solutions were found to be the "5% K_2CO_3 + 1% olive oil" solution for the Bineteti variety and the "5% K_2CO_3 + 2% hazelnut oil" solution for the Zeyti variety. It was determined that the pre-treatment solutions recommended for the varieties increased raisin quality and shortened the drying time, and had positive effects on the total phenolic content and antioxidant activity.

Keywords: Dimension reduction, Principal component analysis (PCA), Cluster analysis

1. Introduction

Increasing consumer awareness in food consumption has led to a rising interest in functional foods that positively affect health. Raisins, which contain many bioactive compounds, are considered functional foods and have continuously increasing consumption potential (Papadaki et al. 2021). Nutrients and bioactive compounds in functional foods lead to a healthier and longer life by protecting and controlling non-communicable diseases, especially in populations with genetic predispositions (Abuajah et al. 2015).

The wax layer on the grape berry is a protective barrier against fungal pathogens, controls gas exchange between the berry and the external environment, reduces water loss by transpiration, and provides protection against ultraviolet rays and physical injuries. The most notable disadvantage of the wax layer is that it prevents moisture removal during the drying process. Consequently, to remove the wax layer on grape berries and accelerate water diffusion, it is necessary to subject grapes to pre-treatment before drying (Esmaili et al. 2007). The pre-treatment performed before drying provides significant advantages in terms of shortening the drying time and improving the quality of raisins (Christensen & Peacock 2000). Physical and chemical pre-treatments are used to remove the wax layer on the grape berries (Wang et al. 2016). Sodium hydroxide (NaOH), potassium hydroxide (KOH), potassium mete bisulfate ($K_2S_2O_5$), potassium carbonate (K_2CO_3), sodium carbonate (Na_2CO_3), methyl and ethyl ester emulsions are the main chemical substances used in the preparation of pre-treatment solutions (Saravacos et al. 1988; Kassem et al. 2011; Doymaz & Altıner 2012; Patidar et al. 2021). Numerous studies have been conducted regarding the effects of pre-treatment solutions on raisin quality and drying characteristics (Khiari et al. 2021; Foshanji et al. 2022). The effects of various pre-treatments on hormones, enzymes, vitamins, minerals, and phenolic composition in raisins have been analyzed using PCA analysis (Keskin et al. 2022; Olivati et al. 2022).

Today, many of the chemical substances used in the preparation of pre-treatment solutions pose significant risks in terms of food safety and human health (Carranza-Concha et al. 2012; Farias et al. 2021). To minimize or entirely eliminate these risks is possible by using pre-treatment solutions prepared using chemicals and natural additives permissible in foods. In this study, pre-treatment solutions were used, which were obtained by mixing potassium carbonate and sodium bicarbonate with olive oil, hazelnut oil, and sesame oil at different concentrations. The use of potassium carbonate (K_2CO_3) (E501) and sodium bicarbonate ($NaHCO_3$) (E500) as food additives has been approved by both international organizations and the 'Turkish Food Codex Food Additives Regulation' (Anonymous 2013). As the pre-treatment solutions used in the study do not pose a risk in terms of human health, they will contribute to resolving residue problem in raisins. Many factors such as irrigation, nutrition, pruning, crop load, harvest time, disease and pest control, drying technique, pre-treatment solution, environmental conditions, variety, the sugar content of fresh grapes, and moisture content of raisins affect the drying characteristics and raisin quality (Jalili Marandi 1996; Çelik et al. 1998).

Physical, chemical, and sensory analyses are required to define drying characteristics and raisin quality. Although classical methods used to statistically evaluate the large number of data obtained from these analyses provide significant information according to each variable, they are insufficient to reveal the relationships between two or more variables (Doğan et al. 2021). By ignoring other variables, examining the relationships between variables as binary facilitates calculation and interpretation, but is insufficient to explain fully the original relationship structure. There are complex linear and non-linear relationship structures between variables. For this reason, there is a need for multivariate statistical analysis methods that can preserve the relationship structure between the original variables and facilitate interpretation, in other words, perform dimension reduction. One of these methods is the Principal Component Analysis (PCA). When the assumptions of PCA (linearity and numerical variables) cannot be met, non-linear a principal component analysis (NLPCA) is used as an alternative method (Linting et al. 2007; Kapucu 2016). NLPCA is a complementary and explanatory dimension reduction method that determines the direction and degree of relationships between variables in multivariate data sets with linear or non-linear relationships and shows the results numerically and visually (Kramer 1991; Kapucu 2016).

In the literature review conducted, it was observed that the use of multivariate analysis methods considering the categorical and continuous variables together and presenting the relationship structure between these variables in a simple and understandable way is limited. For this reason, NLPCA was used to determine the relationships between categorical, continuous, and ordinal variables in this study. In addition, a cluster analysis was performed to determine the prominent pre-treatment solutions in terms of drying characteristics and raisin quality.

This study aims to evaluate the relationships between pre-treatment solution, variety, drying characteristics, and raisin quality in raisin production using multivariate analysis methods (PCA, cluster analysis, and correlation analysis).

2. Material and Methods

2.1. Material

This study was carried out in 2020 on Bineteti and Zeyti local seed grape varieties considered as drying in Gercüş (Batman-Turkey) province. The cluster density is “dense” in the Bineteti variety and “medium” in the Zeyti variety, and the berries of both varieties are green-yellow in colour, short-oval shaped, juicy, and have a very thin skin and a weak wax layer. The average cluster and berry weights are 695.0±111.2 g and 3.63±0.52 g in the Bineteti variety and 659.5±128.02 g and 3.87±0.56 g in the Zeyti variety, respectively (Kırs 2019). The research material was obtained from a producer vineyard in Gercüş (Batman-Turkey) province. During the drying period, the average air temperature and humidity were measured as 28.18±2.07 °C and 21.01±4.74%, respectively.

2.2. Method

The grapes were harvested when the soluble solid content (SSC) reached 22.26% in the Bineteti variety and 22.03% in the Zeyti variety. After the grapes were harvested, diseased and damaged berries were removed, and large bunches were separated into smaller bunches. The grapes were dipped in 13 different pre-treatment solutions 8-10 times and then dried in the sun on a concrete drying platform. In the preparation of pre-treatment solutions, high-purity (98-99% purity) potassium carbonate (K_2CO_3) and sodium bicarbonate ($NaHCO_3$) with high acidity (2-4%) olive oil, hazelnut oil, and sesame oil were used. The formulations of pre-treatment solutions used in the study are presented in Table 1. The drying process was stopped when the moisture content of the grapes reached 15-16% (Çelik et al. 1998; Anonymous 1979; 2002).

Table 1- The formulations of pre-treatment solutions used in the study

No	*The formulations of pre-treatment solutions*
1	Control
2	5% Potassium Carbonate (K_2CO_3) + 1% Olive Oil
3	5% Potassium Carbonate (K_2CO_3) + 2% Olive Oil
4	5% Potassium Carbonate (K_2CO_3) + 1% Hazelnut Oil
5	5% Potassium Carbonate (K_2CO_3) + 2% Hazelnut Oil
6	5% Potassium Carbonate (K_2CO_3) + 1% Sesame Oil
7	5% Potassium Carbonate (K_2CO_3) + 2% Sesame Oil
8	5% Sodium Bicarbonate ($NaHCO_3$) + 1% Olive Oil
9	5% Sodium Bicarbonate ($NaHCO_3$) + 2% Olive Oil
10	5% Sodium Bicarbonate ($NaHCO_3$) + 1% Hazelnut Oil
11	5% Sodium Bicarbonate ($NaHCO_3$) + 2% Hazelnut Oil
12	5% Sodium Bicarbonate ($NaHCO_3$) + 1% Sesame Oil
13	5% Sodium Bicarbonate ($NaHCO_3$) + 2% Sesame Oil

The drying time and drying yield were examined as drying characteristics, while moisture content, 100 raisin weight, surface colour values [L^*, a^*, b^*, *a/b*, chroma (C^*), hue ($h°$)], total acidity, SSC, pH value, total phenolic content, and antioxidant activity (total 15 numeric variables) were examined as raisin quality characteristics. The drying yield was calculated as the ratio of the total weight of fresh grapes to the total weight of raisins obtained after drying (Boztepe 2012). The moisture content of the raisins was determined by drying 50 g of the raisin sample in an oven at 65 °C until a constant weight was reached (Yıldırım 2018). The L^*, a^*, and b^* values of raisins were determined using Photoshop CS6 software from the JPEG format images taken at the same light intensity in the photo booth. Chroma (C^*) and hue ($h°$) values were obtained from the L^*, a^*, and b^* values by using the Ral Digital 5.0 software (Doğan & Uyak 2020). To determine the total acidity, 40 g of raisin sample was crushed in a mortar and soaked in 100 mL of distilled water for 4 hours. Then, these samples mixed with a mixer were filtered using filter paper. 10 mL of this mixture was taken and titrated until the pH reached a value of 8.1. Total acidity was calculated as tartaric acid (Köylü 1997). SSC measurements were conducted using a digital refractometer on the mixture prepared for the acid analysis. Then, the soluble solid content in the main sample was calculated by considering the dilution ratio (Cemeroğlu 1992). Raisin extract was prepared to determine the total phenolic content and antioxidant activity. For this purpose, 5 g of raisin samples were crushed in a mortar, and then 25 mL of methanol was added and homogenized for 2 minutes. Afterwards, the samples were kept in dark at room temperature for 30 minutes and centrifuged for 15 minutes, and the supernatant portions were transferred to eppendorf tubes and stored at -20°C. The total phenolic content was determined using the Folin-Ciocalteu calorimetric method (Swain & Hillis 1959). 150 µL of the raisin extract was taken and mixed with 2400 µL of distilled water, 150 µL of Folin solution, and 300 µL of 20% sodium carbonate (Na_2CO_3) solution, and this mixture was kept at room temperature for 1 hour. After this process, the absorbance values were read at a wavelength of 725 nm in the spectrophotometer, and the total phenolic content was calculated as gallic acid equivalent (GAE) mg 100 g^{-1} dry weight (Figure 1). The antioxidant activity was determined using the Ferric Reducing Antioxidant Power (FRAP) method (Benzie & Strain 1996). FRAP reagent was prepared by mixing acetate buffer, hydrochloric acid (HCl) solution, TPTZ (2,4,6-tripyridyl-s-triazine) solution, and ferric chloride ($FeCl_3.6H_2O$) solutions in a 10:1:1 ratio. The raisin extracts were first diluted 100 times with methanol, and then 150 µL of the sample was taken and mixed with 2850 µL of FRAP reagent, and this mixture was kept at room temperature for 30 minutes. Then, the absorbance values were read at a wavelength of 593 nm in the spectrophotometer, and the antioxidant activity values were calculated as µmol Trolox equivalent (TE) g^{-1} (Figure 1).

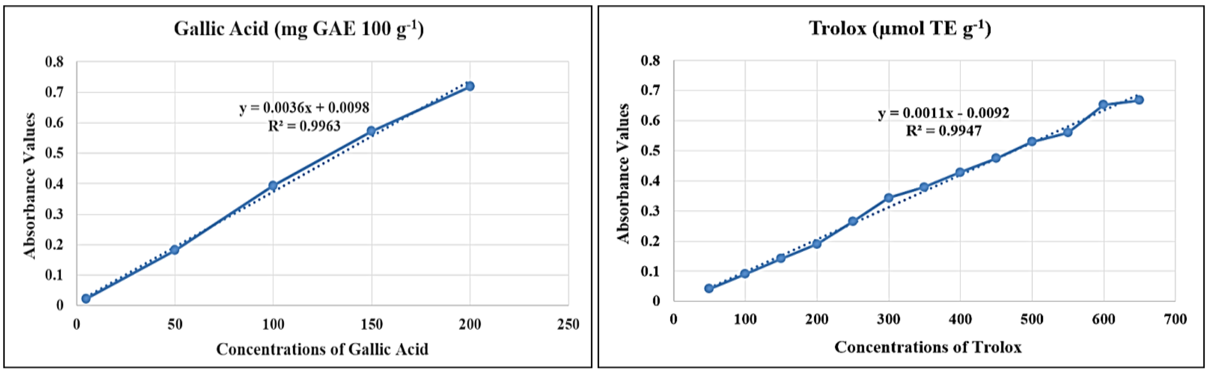


Figure 1- Calibration curves of gallic acid and trolox

2.3. Statistical analysis

The research was carried out according to a completely randomized design with 3 replications and 5 kg of fresh grapes in each replication. The PCA is a dimension reduction method used to obtain a fewer number of new variables (p), called principal components, from the linear combination of k number of original variables ($X1$, $X2$,…,Xk). In PCA, the first two or three principal components that explain most variation in the variables are considered. Thus, it is ensured that variables are summarized and interpreted significantly (Jollife 1986; Demir et al. 2016). To determine the number of appropriate principal components in the PCA, principal components with eigenvalues greater than one are considered (Alpar 2011). To apply PCA, it is required that the relationships between the variables are linear and the variables are on a numerical scale (Jolliffe 1986). However, in many studies, ordinal, categorical, or discrete variables are also used, as well as numerical variables. When the necessary conditions for PCA are not met, NLPCA is recommended as a more appropriate analysis method. NLPCA allows for variables to be scaled at different levels with an optimal scaling approach. As a result, categorical variables are appropriately scaled to the desired dimension. Thus, linear and non-linear relationships between variables can be modelled (Meulman & Heiser 2011; Mori et al. 2016).

In optimal scaling, analyses performed without considering the structure of the variables may not provide accurate results. Therefore, some transformations should be made by considering the variables' structures, and the variables should be transformed into a suitable form for optimal scaling. In this context, smaller dimensional solutions are obtained using non-linear methods by transforming a numerical variable into a categorical variable (Meulman & Heiser 2011; Güç 2015). The NLPCA method offers several notable advantages, including the absence of assumptions such as normality and linearity, and its ability to include nominal and ordinal scale variables in the analysis, unlike PCA. Thus, in data sets containing different types of variables, these variables can be considered together and the relationship structure between them can be presented numerically and visually in a two-dimensional space (Demir et al. 2021). In this study, NLPCA was used because the relationships between the variables in the nominal and ordinal scale were examined. In the study, binary Pearson correlation coefficients between the variables were first calculated in order to test the suitability of numeric variables for PCA. Because the variables for which correlations were calculated were numerical variables and the number of observations was over 30, the Pearson correlation coefficient, which is a parametric correlation, was calculated instead of the Spearman correlation coefficient, which is a non-parametric correlation coefficient. Then, Kaiser-Meyer-Olkin (KMO) and Bartlett Sphericity tests were used. The data of 15 numerical variables were analyzed using PCA. They were reduced to four principal components (PC1, PC2, PC3, and PC4) according to their eigenvalues, and the score values of the principal components were numerically obtained. Then, two varieties, 13 pre-treatment solutions, and the first four principal components obtained by PCA were analyzed by NLPCA. During the analysis, the scores of the first four principal components were converted into a two-group (high and low) categorical variable. The obtained results were interpreted numerically and graphically. PCA and NLPCA analyses were conducted on a total of 78 observations. In addition, a cluster analysis was performed using the JMP Pro software according to the Ward method. A correlation analysis was performed using the "corrplot" package (Wei & Simco 2017) in the R software, and PCA and NLPCA was performed with the SPSS (25.0 version) software. In this study, descriptive statistics for the continuous variables were presented as Mean ± Standard Deviation of Mean. A one-way ANOVA was performed for the comparison of group means. The Duncan multiple comparison test was also used to identify different groups. The statistical significance level was considered as 5%.

3. Results and Discussion

3.1. The effects of pre-treatment solutions on drying characteristics and raisin quality of varieties

It was determined that pre-treatment solutions were effective on drying characteristics (drying time and drying yield) and raisin quality (except total acidity in the Bineteti variety) in both varieties (Table 2). Pre-treatment solutions shortened the drying time in both varieties (Table 2). It has been reported that dipping solutions applied to grapes before drying accelerate the drying process (Esmaili et al. 2007; Matteo et al. 2000; Vázquez et al. 2000; Dev et al. 2008). The moisture content of raisins obtained from all treatments in both varieties varied between 15-16% (Table 2). Previous studies note that the moisture content of raisins should be between 13-18% (Anonymous 1979; 2002). Kapuci et al. (2022) has reported that the moisture contents of raisins varied between 14-15% depending on different drying sites and pre-treatment solutions in the Bineteti and Zeyti varieties. Drying yield varied between 23-25% in the Bineteti variety and 19-21% in the Zeyti variety (Table 2). Kapuci et al. (2022) determined that the drying yields varied between 24-26% for the Bineteti variety and 18-20% for the Zeyti variety depending on different drying sites and pre-treatment solutions. The 100 raisin weight varied between 124.18-133.03 g in the Bineteti variety and 77.32-86.77 g in the Zeyti variety (Table 2). Kapuci et al. (2022) calculated that the 100 raisin weights varied between 127.98-142.80 g in the Bineteti variety and 77.27-88.06 g in the Zeyti variety depending on different drying sites and pre-treatment solutions. It was determined that the L^*, a^*, b^*, chroma (C^*) and hue (h°) values of dipped raisins in both varieties were higher than natural (control) raisins, and their a/b values were lower than natural raisins (Table 2). Dipped raisins showed higher values than natural (control) raisins in terms of total phenolic content and antioxidant activity (Table 2). This may have stemmed from the natural (control) raisins not being subjected to any pre-treatment before drying and being exposed to intense enzymatic browning due to the longer drying times. Many researchers have reported that enzymatic activity reduces the total phenolic content and antioxidant activity in raisins (Yeung et al. 2003; Breksa et al. 2010; Foshanji et al. 2018). It has been stated that the effects of the drying process on phenolic compounds could vary depending on many factors such as drying time, drying environment, and grape variety (Mazlum & Nizamlıoğlu 2021).

Table 2- The effects of pre-treatment solutions on drying characteristics and raisin quality of varieties

Variables	*Drying Time (Day)*		*Moisture Content (%)*		*Drying Yield (%)*		*100 Raisin Weight (g)*	
Varieties	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*
Control	22.33±2.30 a	20.33±1.52 a	15.16±0.57 cd	15.22±0.23 bcd	23.49±0.63 c	20.25±0.97 abcde	126.09±1.96 bcd	80.36±3.05 bcd
%5K_2CO_3+1% Olive Oil	11.33±2.88 b	8.66±1.15 bc	15.32±0.38 bcd	15.71±0.77 abcd	25.83±0.84 a	21.90±0.99 a	133.03±3.29 a	80.89±4.31 bcd
%5K_2CO_3+2% Olive Oil	11.00±1.00 b	8.00±0.00 c	16.36±0.36 a	15.41±0.74 abcd	25.50±0.51 a	20.02±0.86 bcde	124.73±2.29 cd	79.75±3.93 bcd
%5K_2CO_3+1% Hazelnut Oil	12.00±1.73 b	10.00±0.00 b	15.50±0.63 abcd	15.10±0.40 cd	25.56±0.71 a	21.03±0.62 abcd	131.81±3.36 ab	77.39±2.66 cd
%5K_2CO_3+2% Hazelnut Oil	13.00±0.00 b	8.00±0.00 c	15.08±0.39 d	16.19±0.64 ab	24.66±0.63 ab	19.77±0.82 cde	125.03±3.13 cd	80.72±2.44 bcd
%5K_2CO_3+1% Sesame Oil	11.33±1.66 b	9.33±1.15 bc	16.03±0.34 abcd	15.28±0.15 bcd	24.84±0.73 a	20.92±0.28 abcd	124.18±1.83 d	77.56±2.66 cd
%5K_2CO_3+2% Sesame Oil	13.00±0.00 b	8.00±0.00 c	15.11±0.34 d	16.06±0.23 abc	24.73±0.33 a	21.59±0.52 ab	127.55±2.93 abcd	86.77±1.32 a
5%$NaHCO_3$+1% Olive Oil	13.00±0.00 b	9.33±1.15 bc	15.52±0.75 abcd	15.98±0.64 abcd	25.36±0.66 a	21.01±1.09 abcd	131.56±2.74 ab	80.03±2.03 bcd
5%$NaHCO_3$+2% Olive Oil	12.00±1.73 b	8.00±0.00 c	15.48±0.50 abcd	16.33±0.21 a	25.00±0.64 a	19.32±0.63 de	130.21±3.02 abc	77.32±3.54 d
5%$NaHCO_3$+1% Hazelnut Oil	11.33±2.88 b	10.00±0.00 b	16.16±0.65 ab	16.08±0.42 abc	24.63±0.20 ab	21.48±1.58 abc	126.21±2.46 bcd	85.45±1.16 ab
5%$NaHCO_3$+2% Hazelnut Oil	13.00±0.00 b	8.66±1.15 bc	15.10 ±0.17 d	15.54±0.63 abcd	23.58±0.92 bc	19.85±1.11 bcde	126.75±3.47 bcd	83.19±4.73 abc
5%$NaHCO_3$+1% Sesame Oil	11.33±2.88 b	9.33±1.15 bc	16.12±0.40 abc	15.80±0.50 abcd	24.95±0.11 a	20.79±0.68 abcde	126.05±3.27 bcd	80.96±2.40 bcd
5%$NaHCO_3$+2% Ssesame Oil	11.33±2.88 b	9.33±1.15 bc	15.58±0.74	15.03±0.53 d	23.13±0.56 c	19.10±1.12 e	125.52±4.93 cd	78.29±1.72 cd
Variables	**Total Acidity (g/l)**		**Soluble Solids Content (%)**		**pH**		**Total Phenolic Content**	
Varieties	**Bineteti**	**Zeyti**	**Bineteti**	**Zeyti**	**Bineteti**	**Zeyti**	**Bineteti**	**Zeyti**
Control	2.78±0.11 ns	3.39±0.69 ab	80.77±1.67 abc	76.33±2.08 bc	3.87±0.04 c	3.86±0.01 d	253.47±7.77 e	245.03±6.08 c
%5K_2CO_3+1% Olive Oil	2.67±0.32	3.09±0.24abcd	78.22±1.68 cd	78.33±1.85 abc	4.00±0.02 abc	3.95±0.04 abcd	273.96±8.43 bcd	284.69±6.36 ab
%5K_2CO_3+2% Olive Oil	2.54±0.03	3.59±0.03 a	80.55±1.38 abcd	76.44±2.03 bc	3.95±0.03 bc	3.87±0.07 d	280.70±8.64 abcd	290.55±7.96 ab
%5K_2CO_3+1% Hazelnut Oil	2.46±0.22	3.19±0.31 abc	78.99±1.20 bcd	75.88±2.54 bc	3.94±0.04 bc	3.99±0.07 abc	282.82±6.13 abcd	282.72±7.34 ab
%5K_2CO_3+2% Hazelnut Oil	2.73±0.29	3.58±0.16 a	81.33±1.76 ab	79.21±2.14 ab	4.00±0.04 abc	3.88±0.04 cd	278.75±9.03 bcd	284.30±4.47 ab
%5K_2CO_3+1% Sesame Oil	2.57±0.24	3.36±0.44 ab	79.44±1.07 bcd	80.10±1.38 a	3.97±0.08 bc	3.90±0.08 cd	272.10±9.87 cd	289.86±6.51 ab
%5K_2CO_3+2% Sesame Oil	2.99±0.20	2.85±0.34 bcd	80.44±1.39 abcd	76.21±1.26 bc	3.94±0.09 bc	3.89±0.02 cd	298.80±8.87 a	283.91±7.07 ab
5%$NaHCO_3$+1% Olive Oil	2.61±0.28	2.57±0.12 d	79.99±1.85 abcd	77.21±1.50 abc	3.91±0.08 bc	4.02±0.09 ab	269.27±8.36 de	289.16±4.20 ab
5%$NaHCO_3$+2% Olive Oil	2.58±0.07	3.03±0.13abcd	82.33±1.19 a	74.88±1.01 c	3.92±0.06 bc	3.90±0.04 cd	289.86±6.91 abc	282.92±4.79 ab
5%$NaHCO_3$+1% Hazelnut Oil	2.47±0.27	2.64±0.22 cd	80.88±1.01 abc	76.10±1.38 bc	4.09±0.08 a	4.05±0.03 a	271.80±6.75 cd	280.33±7.03 ab
5%$NaHCO_3$+2% Hazelnut Oil	2.67±0.20	2.73±0.35 cd	79.10±1.50 bcd	77.99±1.85 abc	4.00±0.06 abc	3.93±0.09 bcd	280.11±7.73 abcd	292.64±7.31 a
5%$NaHCO_3$+1% Sesame Oil	2.68±0.24	3.08±0.20abcd	78.10±1.67 cd	75.10±1.07 c	3.94±0.03 bc	3.96±0.04 abcd	292.89±5.69 ab	280.14±6.12 ab
5%$NaHCO_3$+2% Sesame Oil	2.55±0.31	2.70±0.19 cd	77.83±0.70 d	76.21±2.21 bc	4.04±0.08 ab	3.97±0.05 abcd	281.81±5.98 abcd	275.02±5.73 ab

a, b, c ↓ The differences between treatments with different letters in the same column are statistically significant ($P<0.05$), ns: No significant

Table 2- The effects of pre-treatment solutions on drying characteristics and raisin quality of varieties (Continued)

Variables	*Antioxidant Activity*		L^*		a^*		b^*	
Varieties	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*	*Bineteti*	*Zeyti*
Control	8.20±1.13 c	7.20±1.12 d	23.33±0.36 h	21.87±0.52 g	17.25±0.09 c	18.56±0.09 h	14.55±0.11 g	15.15±0.21 g
%5K_2CO_3+1% Olive Oil	10.55±0.91 bc	9.00±1.45 cd	35.51±0.90 a	33.60±0.60 ab	25.53±0.03 a	26.63±0.44 a	29.26±0.83 a	30.48±0.53 a
%5K_2CO_3+2% Olive Oil	12.09±0.94 ab	12.66±0.95 a	30.90±0.45 fg	31.90±0.81 cd	23.32±0.75 b	19.96±0.38 g	26.23±0.62 e	23.81±0.15 f
%5K_2CO_3+1% Hazelnut Oil	12.52±0.96 ab	9.55±1.11 abcd	31.78±0.93 def	30.86±0.85 def	25.09±0.27 a	24.39±0.28 cd	27.50±0.57 cd	27.04±0.81 cd
%5K_2CO_3+2% Hazelnut Oil	10.12±1.01 bc	12.50±1.32 ab	32.38±1.03 cde	32.93±0.42 bc	24.85±0.35 a	25.44±0.18 b	28.91±0.74 ab	26.99±0.51 cd
%5K_2CO_3+1% Sesame Oil	11.34±1.20 ab	9.84±1.35 abcd	34.55±0.80 ab	31.67±0.89 de	24.71±0.16 a	23.75±0.21 e	29.77±0.07 a	26.34±0.25 de
%5K_2CO_3+2% Sesame Oil	13.23±1.16 a	9.48±1.61 bcd	32.41±0.73 cde	34.35±0.43 a	23.84±0.38 b	25.38±0.46 b	26.70 0.33 de	29.04±0.56 b
5%$NaHCO_3$+1% Olive Oil	10.16±0.95 bc	9.20±1.51 cd	33.69±0.85 bc	32.08±0.56 cd	25.38±0.16 a	24.56±0.21 c	28.86±0.19 ab	26.45±0.24 de
5%$NaHCO_3$+2% Olive Oil	11.88±1.30 ab	10.81±1.06 abc	33.63±0.96 bc	30.31±0.70 f	24.95±0.25 a	23.94±0.61 de	28.03±0.29 bc	25.74±0.87 e
5%$NaHCO_3$+1% Hazelnut Oil	11.73±1.26 ab	9.30±1.26 cd	31.18±0.56 efg	30.51±0.42 ef	24.73±0.16 a	24.47±0.41 cd	27.19±0.68 cd	25.45±0.89 e
5%$NaHCO_3$+2% Hazelnut Oil	10.12±1.08 bc	12.48±1.30 ab	31.17±0.73 efg	33.55±0.85 ab	23.35±0.20 b	26.19±0.46 a	25.07±0.84 f	27.56±0.45 c
5%$NaHCO_3$+1% Sesame Oil	10.13±0.90 bc	10.80±1.03 abc	30.27±0.43 g	30.38±0.98 f	23.79±0.93 b	21.42±0.11 f	26.05±0.23 e	24.29±0.71 f
5%$NaHCO_3$+2% Ssesame Oil	10.31±1.06 bc	9.98±1.41 abcd	32.64±0.71 cd	34.32±0.22 a	25.16±0.54 a	24.71±0.13 c	27.61±0.28 cd	27.11±0.69 cd
Variables	***a/b***		**Croma (C^*)**		**Hue (h°)**			
Varieties	**Bineteti**	**Zeyti**	**Bineteti**	**Zeyti**	**Bineteti**	**Zeyti**		
Control	1.18±0.01 a	1.22±0.01 a	22.57±0.06 g	23.96±0.16 ı	40.14±0.33 g	39.23±0.38 g		
%5K_2CO_3+1% Olive Oil	0.87±0.01 cd	0.87±0.02 ef	38.83±0.85 a	40.48±0.36 a	48.88±0.43 bc	48.86±0.57 b		
%5K_2CO_3+2% Olive Oil	0.88±0.01 bcd	0.83±0.01 f	35.10±0.66 ef	31.07±0.21 h	48.33±0.47 cde	50.02±0.63 a		
%5K_2CO_3+1% Hazelnut Oil	0.91±0.02 bc	0.90±0.01 de	37.24±0.68 cd	36.42±0.78 cd	47.60±0.57 e	47.93±0.56 bcd		
%5K_2CO_3+2% Hazelnut Oil	0.86±0.03 de	0.94±0.01 bcd	38.14±0.46 abc	37.10±0.43 c	49.31±0.59 b	46.68±0.52 ef		
%5K_2CO_3+1% Sesame Oil	0.83±0.03 e	0.90±0.01 de	38.69±0.15 a	35.47±0.06 ef	50.30±0.11 a	47.96±0.52 bcd		
%5K_2CO_3+2% Sesame Oil	0.89±0.04 bcd	0.87±0.03 ef	35.80±0.50 e	38.58±0.20 b	48.23±0.15 cde	48.84±0.58 b		
5%$NaHCO_3$+1% Olive Oil	0.87±0.05 cd	0.92±0.04 bcd	38.43±0.22 ab	36.10±0.31 de	48.67±0.17 bcd	47.11±0.12 def		
5%$NaHCO_3$+2% Olive Oil	0.89±0.01 bcd	0.93±0.03 bcd	37.52±0.07 bcd	35.16±0.60 f	48.32±0.58 cde	47.06±0.54 def		
5%$NaHCO_3$+1% Hazelnut Oil	0.91±0.02 bc	0.96±0.04 b	36.75±0.54 d	35.55±0.27 ef	47.70±0.68 de	46.50±0.73 f		
5%$NaHCO_3$+2% Hazelnut Oil	0.93±0.03 b	0.95±0.03 bc	34.27±0.54 f	38.03±0.31 b	45.35±0.49 f	46.44±0.53 f		
5%$NaHCO_3$+1% Sesame Oil	0.91±0.04 bc	0.88±0.03 ef	34.79±1.06 f	32.33±0.80 g	48.87±0.70 bc	48.65±0.53 bc		
5%$NaHCO_3$+2% Sesame Oil	0.91±0.02 bc	0.91±0.01 cde	37.35±0.25 cd	36.68±0.59 cd	47.66±0.86 e	47.64±0.611 cde		

a, b, c ↓ The differences between treatments with different letters in the same column are statistically significant ($P<0.05$).

3.2. Principal component analysis

In the study, the Kaiser-Meyer-Olkin (KMO) value was found to be 0.777, and accordingly, it was observed that 15 original continuous variables were dimensionally reducible with the principal component or factorable (suitable for PCA analysis). This value is considered sufficient when it is above 0.50 by Field (2009) and classified in the 'good' category among 0.70-0.80. The result of the Bartlett Sphericity test ($\chi^2(105)=1683.701$; $P<0.001$) indicated that the correlations among the variables were large enough for PCA analysis.

According to the PCA result, while PC1 explained 45.1% of the total variance, PC2, PC3, and PC4 explained 20.2%, 9.9%, and 6.8% of the total variance, respectively. The first four principal components explained 82.1% of the variation in the original variables. In other words, 15 variables were reduced to four principal components, explaining approximately 82% of the total variance (Table 3). Loading values equal to or greater than 0.40 are accepted as ideal in determining the contribution of variables to principal components (Field 2009). Accordingly, L^*, a^*, b^*, chroma (C^*), hue (h°), a/b, antioxidant activity, total phenolic content, and drying time were the variables that contributed the most to PC1. The variables of a/b value and drying time had a negative effect on the PC1, whereas the other variables had a positive effect. The total acidity, SSC, drying yield, 100 raisin weight, and drying time were the variables that contributed the most to PC2. The total acidity variable had a negative effect on the PC2, whereas the other variables had a positive effect. Antioxidant activity, total acidity, SSC, and pH were the variables that contributed the most to PC3. The pH variable had a negative effect on the PC3, whereas the other variables had a positive effect. Only the moisture content variable provided the highest positive contribution to PC4 (Table 3).

Table 3- Load values of the first four principal components and variance ratios explained by them

Variables	*Unit*	*PC1*	*PC2*	*PC3*	*PC4*
L^*	-	**0.937**	-0.030	0.039	-0.140
a^*	-	**0.859**	0.027	-0.204	-0.131
b^*	-	**0.972**	0.029	-0.056	-0.127
Croma (C^*)	-	**0.946**	0.027	-0.121	-0.130
hue (h°)	-	**0.911**	-0.053	0.131	0.005
a/b	-	**-0.923**	0.041	-0.123	0.048
AA	µmol TE g^{-1}	**0.527**	0.079	**0.501**	0.345
TPC	mg GAE 100 g^{-1}	**0.694**	-0.231	0.296	-0.022
TA	g l^{-1}	-0.250	**-0.648**	**0.519**	-0.061
SSC	%	0.092	**0.671**	**0.436**	0.079
pH	-	0.322	0.240	**-0.711**	-0.034
MC	%	0.235	-0.141	-0.264	**0.888**
DY	%	0.219	**0.910**	0.092	0.051
100 RW	g	0.127	**0.936**	0.118	0.063
DT	Day	**-0.758**	**0.567**	0.063	-0.162
Eigenvalue	-	6.765	3.042	1.492	1.025
Explained variance	(%)	45.1	20.2	9.9	6.8
Cumulative variance	(%)	45.1	65.3	75.3	82.1

AA: Antioxidant Activity; **TPC**: Total Phenolic Content; **TA**: Total Acidity; **SSC**: Soluble Solids Content; **MC**: Moisture Content; **DY**: Drying Yield; **RW**: Raisin Weight; **DT**: Drying Time; **TE**: Trolox Equivalent; **GAE**: Gallic Acid Equivalent

The relationship structure between two factors (variety and pre-treatment solution) and the four principal components obtained from the reduction of 15 variables was examined using NLPCA. The score values of the principal components obtained through PCA were obtained numerically. However, the scores of the first four principal components used for NLPCA were transformed into a two-group categorical variable for a more understandable interpretation. As discriminative power and contribution of the categories to the dimensions increase, the coefficient values of the dimensions also increase. In other words, as the values any category takes on the dimensions deviate from the origin, the effect of this category in determining the dimension increase also (Demir et al. 2021). The categories of the variables and their vector coordinates in two-dimensional space were presented in Table 4. When both dimensions were evaluated together, the pre-treatment solution strongly affected the variables that made up PC1, while it weakly affected the other variables. According to this analysis, it was observed that the pre-treatment solution had a significant effect on the colour values, total phenolic content, antioxidant activity, and drying time. Similar results have also been reported by other researchers (Doymaz & Altıner 2012; İşçi & Altındişli 2016; Zemni et al. 2017; Çelik 2019; Khiari et al. 2021; Kapuci et al. 2022). A positive correlation was observed between the 1st, 3rd, 10th, 11th, and 12th pre-treatment solutions and the '-3-0' category of PC1, the '0-2' categories of PC3 and PC4 (Table 4). In the same way a positive relationship was found between the 2nd, 5th, 6th, 7th, 8th, 9th, and 13th pre-treatment solutions and '0-0' category of PC1, '-2-0' categories of PC3 and PC4. A negative relationship was determined between these two groups of variables with a positive relationship. Furthermore, a strong relationship was found between the variety and PC2. It was observed that Bineteti variety had a positive effect on the total acidity, SSC, drying yield, 100 raisin weight, and drying time variables that form PC2. The NLPCA showed which variety is more suitable for drying. Variables that cause PC2 discrimination are among the factors affecting the drying yield and raisin quality. Many studies note that these factors are positively or negatively associated with the variety (Yalçınkaya 2016; Çelik 2019; Kapuci et al. 2022). However, Table 4 shows that the relationships between variety and

PC2 variables and other variables were weak. It was determined that the Bineteti variety was positively correlated with the '0-1' category of PC2, and the Zeyti variety was positively correlated with the '-1-0' category of the same principal component (Table 4). This analysis results revealed that the Bineteti variety had a higher performance than the Zeyti variety in terms of drying yield and raisin quality. In PCA, the PC1 always has the highest variance explanation ratio, while the last principal component has the lowest variance explanation ratio (Demir et al. 2021). Therefore, in NLPCA, the low variance explanation ratios of PC3 and PC4 compared to other principal components also affects the relationship of these variables with other variables. In this context, it was observed that the PC3 and PC4 variables were weakly correlated with the other variables (Table 4).

Table 4- Categories of variables and their vector coordinates in two-dimensional space

		Vector Coordinates	
Variables	***Category***	***1stDimension***	***2ndDimension***
Variety	Bineteti	0.986	-0.044
	Zeyti	-0.986	0.044
Pretreatment Solutions	1.Control	0.039	1.246
	2.5%K_2CO_3+1% Olive Oil	-0.029	-0.905
	3. 5%K_2CO_3+2% Olive Oil	0.003	0.085
	4. 5%K_2CO_3+1% Hazelnut Oil	-0.001	-0.027
	5. 5%K_2CO_3+2% Hazelnut Oil	-0.025	-0.793
	6. 5%K_2CO_3+1% Sesame Oil	-0.023	-0.736
	7. 5%K_2CO_3+2% Sesame Oil	-0.025	-0.793
	8. 5%$NaHCO_3$+1% Olive Oil	-0.013	-0.424
	9. 5%$NaHCO_3$+2% Olive Oil	-0.010	-0.312
	10.5%$NaHCO_3$+1%Hazelnut Oil	0.066	2.100
	11.5%$NaHCO_3$+2%Hazelnut Oil	0.012	0.370
	12.5%$NaHCO_3$+1%Sesame Oil	0.034	1.077
	13.5%$NaHCO_3$+2%Sesame Oil	-0.028	-0.889
PC1	-3.53061- -0.00036	0.112	1.328
	0.02334 - 0.93847	-0.053	-0.626
PC2	-1.67041- -0.02001	-0.958	0.029
	0.16779 - 1.78391	1.008	-0.030
PC3	-2.61137- -0.02024	-0.280	-0.144
	0.00396 - 2.12636	0.266	0.136
PC4	-2.03316- -0.03591	-0.028	-0.325
	0.00988 - 2.11238	0.032	0.379

After optimal scaling, the total variance explanation ratios of the first and second dimensions were 34.0 and 29.9%, respectively, and these two dimensions explained 64.0% of the total variance. The eigenvalues were found to be 2.044 for the first dimension and 1.796 for the second dimension. According to the first dimension, variety and PC1 constituted positive loading variables, while others constituted negative loading variables. According to the second dimension, PC1 and PC2 constituted positive loading variables, while others constituted negative loading variables. Variety (0.925) and PC2 (-0.926) were the most effective variables in determining the first dimension, while pre-treatment solution (-0.864) and PC1 (0.844) were the most effective variables in determining the second dimension (Table 5).

Table 5- After optimal scaling, component loadings of variables in two-dimensional space and variance ratios explained by dimensions

	Component Loadings	
Variables	***1stDimension***	***2nd Dimension***
Variety	**0.925**	-0.345
Pre-treatment Solution	-0.310	**-0.864**
PC1	0.354	**0.844**
PC2	**-0.926**	0.330
PC3	-0.303	-0.049
PC4	-0.136	-0.325
Eigenvalue	2.044	1.796
Explained variance (%)	34.0	29.9
Cumulative variance (%)	**64.0**	

A strong negative relationship was found between variety and PC2 and pre-treatment solution and PC1. It was observed that the variety and PC2 were not associated with PC1, PC4, and pre-treatment solution. It was seen that variety was also partially associated with PC3, but this relationship was weaker than that between variety and PC2. Similarly, it was observed PC1 was associated with PC4, but this relationship was weaker than that between PC1 and the pre-treatment solution. In general, variables far from the origin have higher variance explanation ratios, while variables close to the origin have lower variance explanation ratios (Demir et al. 2021). In this context, it was observed that the variance explanation ratios of the PC3 and PC4 variables due to their proximity to the origin were low, and their relationships with the other variables were very weak (Figure 2).

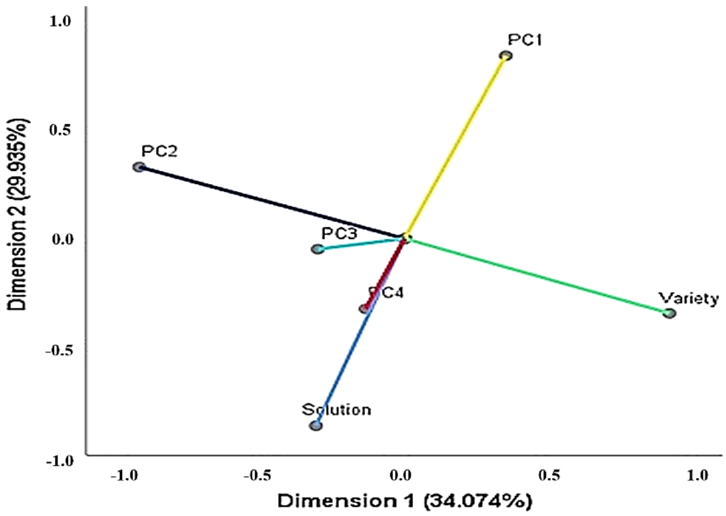


Figure 2- Configuration of variables in two-dimensional space after optimal scaling

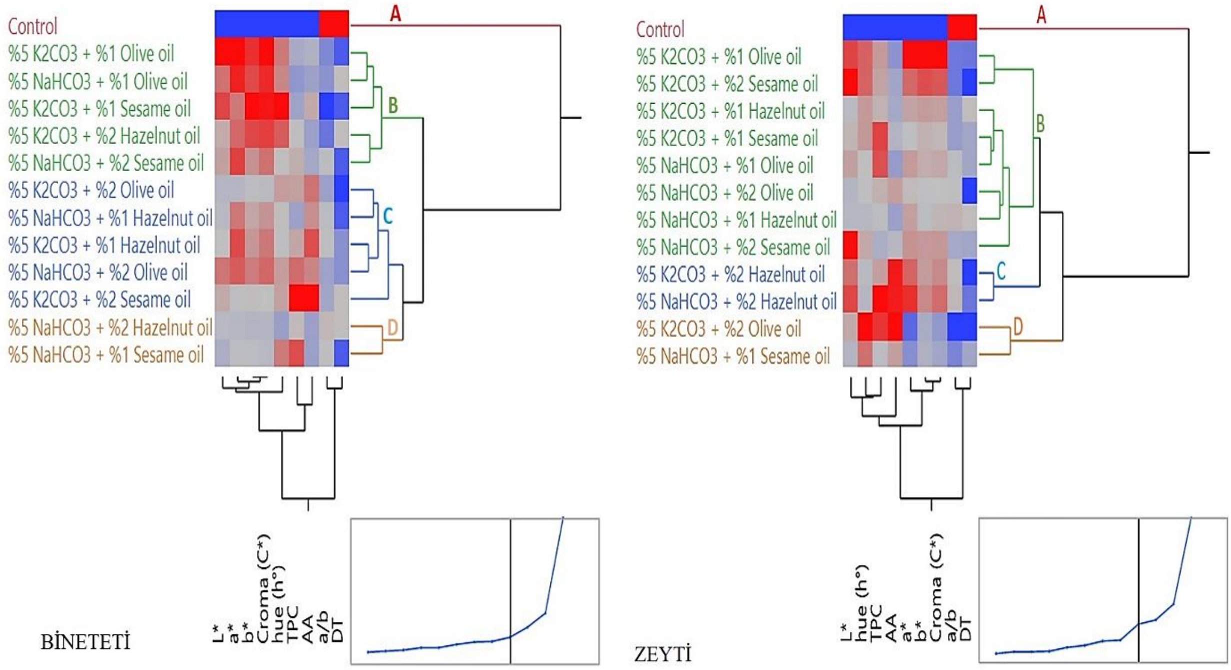
3.3. Cluster analysis

In the study, the pre-treatment solutions in both cultivars yielded significant results compared to the control application. According to cluster analysis, control applications in both varieties were separated from other applications as a distinct group. This distinction clearly indicated that treating the grapes with the pre-treatment solution was necessary before drying. When the cluster separation values were examined in terms of the effectiveness of the pre-treatment solutions, the B cluster in the Bineteti variety and the C cluster in the Zeyti variety were the prominent groups (Table 6). For the Bineteti variety, the best pre-treatment solutions were found to be "5% K_2CO_3 + 1% Olive oil", "5% $NaHCO_3$ + 1% Olive oil", "5% K_2CO_3 + 1% Sesame oil", "5% K_2CO_3 + 2% Hazelnut oil" and "5% $NaHCO_3$ + 2% Sesame oil" solutions. For the Zeyti variety, the best pre-treatment solutions were found to be "5% K_2CO_3 + 2% Hazelnut oil" and "5% $NaHCO_3$ - 2% Hazelnut oil" solutions. It was observed that the "5% K_2CO_3 + 2% Hazelnut oil" pre-treatment solution took place in both prominent clusters for varieties (Figure 3).

Table 6- Cluster analysis according to some quality characteristics and drying times of the two varieties

Variety	*BİNETETİ*				*ZEYTİ*				
Cluster	*A*	*B*	*C*	*D*	*Cluster*	*A*	*B*	*C*	*D*
Count	*1*	*5*	*5*	*2*	*Count*	*1*	*8*	*2*	*2*
L^*	23.33 c	33.75 a	31.98 b	30.72 b	***L^****	21.87 c	32.21 b	33.24 a	31.14 b
a^*	17.25 c	25.12 a	24.38b	23.57ab	***a^****	18.56d	24.72 b	25.81 a	20.69 c
b^*	14.55 d	28.88 a	27.13 b	25.56c	***b^****	15.15 c	27.20 a	27.27 a	24.05 b
a/b	1.18 a	0.87 c	0.89 c	0.92b	***a/b***	1.22 a	0.94 b	0.91 b	0.86 c
Croma(C^*)	22.57 d	38.28 a	36.48 b	34.53c	**Croma(C^*)**	23.96 c	36.80 a	37.56 a	31.70 b
hue (*h*°)	40.14 c	48.96 a	48.03 a	47.11b	**hue (*h*°)**	39.23 c	46.56 b	47.73 b	49.33 a
TPC	253.47c	275.17b	285.39a	286.50a	**TPC**	245.0c	283.57ab	288.47a	285.34ab
DT	22.33 a	11.99ab	11.86ab	12.16b	**DT**	20.33 a	9.08 b	8.33 c	8.66 c
AA	8.20 c	10.49 b	12.29 a	10.12b	**AA**	7.20 d	9.64 c	12.49 a	11.73 b

a, b, c → The differences between cluster averages with different letters in the same row are statistically significant ($P<0.05$). **TPC:** Total Phenolic Content; **DT:** Drying Time; **AA:** Antioxidant Activity



TPC: Total Phenolic Content, **DT:** Drying Time, **AA:** Antioxidant Activity

Figure 3- Dendogram of cluster analysis for the two varieties

It was observed that the mean values taken in terms of variables of the other pre-treatment solutions in the prominent clusters were close to each other. In this case, the pre-treatment solutions in the prominent clusters can be used as alternatives to each other. It has been reported that the olive oil used in pre-treatment solutions increase raisin's drying speed, elasticity and quality (Doymaz & Pala 2002; Akdeniz 2011). The disadvantage of olive oil used in pre-treatment solutions is that it causes an undesirable taste, aroma, and odour in dipped raisins. Sesame and hazelnut oils can be mixed with many medicinal and aromatic oils due to their indistinctive structure in terms of odour and colour and their soft structure. As a result of the sensory analysis, it was determined that sesame and hazelnut oils could be used as an alternative to olive oil in the preparation of pre-treatment solutions. It was observed that the pre-treatment solutions significantly affected the total phenolic content and antioxidant activity. This effect is thought to be due to the reduction of the drying time by pre-treatment solutions and the additional contribution of the oil components in the solution to the total phenolic content and antioxidant activity. It has been stated that a high L^* value and low a/b value in raisins obtained from varieties with a green-yellow skin colour caused a brighter and more yellow colour formation (İsmail 2005; Chayjan et al. 2011; Doymaz & Altıner 2012). The average L^* and a/b values in the prominent classes for the varieties were found to be compatible with the literature. The chroma (C^*) value, which indicates the saturation of the colour and directly appeals to colour perception, shows low values in dull colours and high values in vivid colours (Mc Guire 1992). It was observed that the average chroma (C^*) values in the prominent clusters in our study were higher than those in the other clusters. The evaluation of L^*, a/b, and chroma (C^*) values showed that the pre-treatment solutions used in our study caused more bright, vivid, and yellow-coloured raisins to be obtained. It should be considered that colour parameters may vary according to grape varieties. A colour quality criterion for grape varieties with a green-yellow berry skin colour can be formed based on high L^*, chroma (C^*), hue (h°) values, and low a/b values. It was observed that the effectiveness of the pre-treatment solutions used in our study might differ according to the berry characteristics and contents of the varieties. In this study, variables showing close values to each other in the groups forming in cluster separation were not included in the cluster analysis.

3.4. Correlation analysis

Statistically significant (P<0.01-0.001) positive and negative correlations were determined between the drying time and other variables (except for total acidity and pH value). Statistically significant (P<0.001) negative correlations (r=from -0.60 to 0.71) were found between drying time and L^*, a^*, b^*, chroma (C^*), hue (h°) values, and total phenolic content. A statistically significant (P<0.001) positive correlation (r=0.72) was observed between the drying time and a/b value (Figure 4). It has been reported that the colour values of raisins were adversely affected depending on the length of the drying time (Özel & İlhan 1980; Akdeniz 2011). In addition, previous studies found that enzymatic activity decreased the total phenolic content and antioxidant activity in raisins depending on the drying time (Yeung et al. 2003; Breksa et al. 2010; Foshanji et al. 2018). The strong negative correlations found between the drying time and colour values, and total phenolic content in the study supported the results of other researchers. Statistically significant (P<0.001) negative correlations (r=from -0.63 to 0.97) were determined between the a/b value and L^*, a^*, b^*, chroma (C^*), hue (h°) values, and total phenolic content. (Figure 4). It was observed that a/b and hue (h°) values were a lower correlation with a^* value and a higher correlation with b^* value. It was found that the b^* value was more effective than the a^* value on the colour formed after drying in the grape varieties examined. Statistically significant (P<0.001) negative correlations (r= from -0.50 to 0.55) were determined between total acidity and drying yield, 100 raisin weight, and pH value (Figure 4). Statistically significant (P<0.001) positive correlations (r= from 0.50 to 0.64) were also found between total phenolic content and a^*, b^*, chroma (C^*), hue (h°) values, and antioxidant activity (Figure 4). The effect of phenolic compounds on colour can explain the correlations between the total phenolic content and colour variables. It has been reported that phenolic compounds are effective in colour formation in raisins (Yueng et al. 2003). The correlations between the total phenolic content and antioxidant activity originated from the antioxidant properties of phenolic compounds. Statistically significant (P<0.001) positive correlations (r= from 0.62 to 0.87) were found between hue (h°) value and a^*, b^*, chroma (C^*), and L^* values (Figure 4). Statistically significant (P<0.001) positive correlations were determined between L^* value and a^* (r=0.81), b^* (r=0.93) and chroma (C^*) (r=0.91) values (Figure 4). Statistically significant (P<0.001) positive correlations were found between the chroma (C^*) value and a^* (r=0.96) and b^* (r=0.99) values (Figure 4). A statistically significant (P<0.001) positive correlation was determined between the b^* value and the a^* value (r=0.91) (Figure 4). Positive correlations between colour values (except for a/b) demonstrated that these variables affected each other. Considering that three main colours form the foundation of the colour space, it can be expressed that these variables are prone to interact with each other. Statistically significant (P<0.001) positive correlations were determined between 100 raisin weight and the SSC (r=0.60) and drying yield (r=0.92) (Figure 4). A statistically significant (P<0.001) positive correlation was determined between the drying yield and the SSC (r=0.59) (Figure 4). While the increase in the soluble solids content has a positive effect on the drying yield, the increase in the total acidity has a negative effect on the drying yield. It has been reported that there was a positive relationship between the SSC and the drying yield (Çelik et al. 1998).

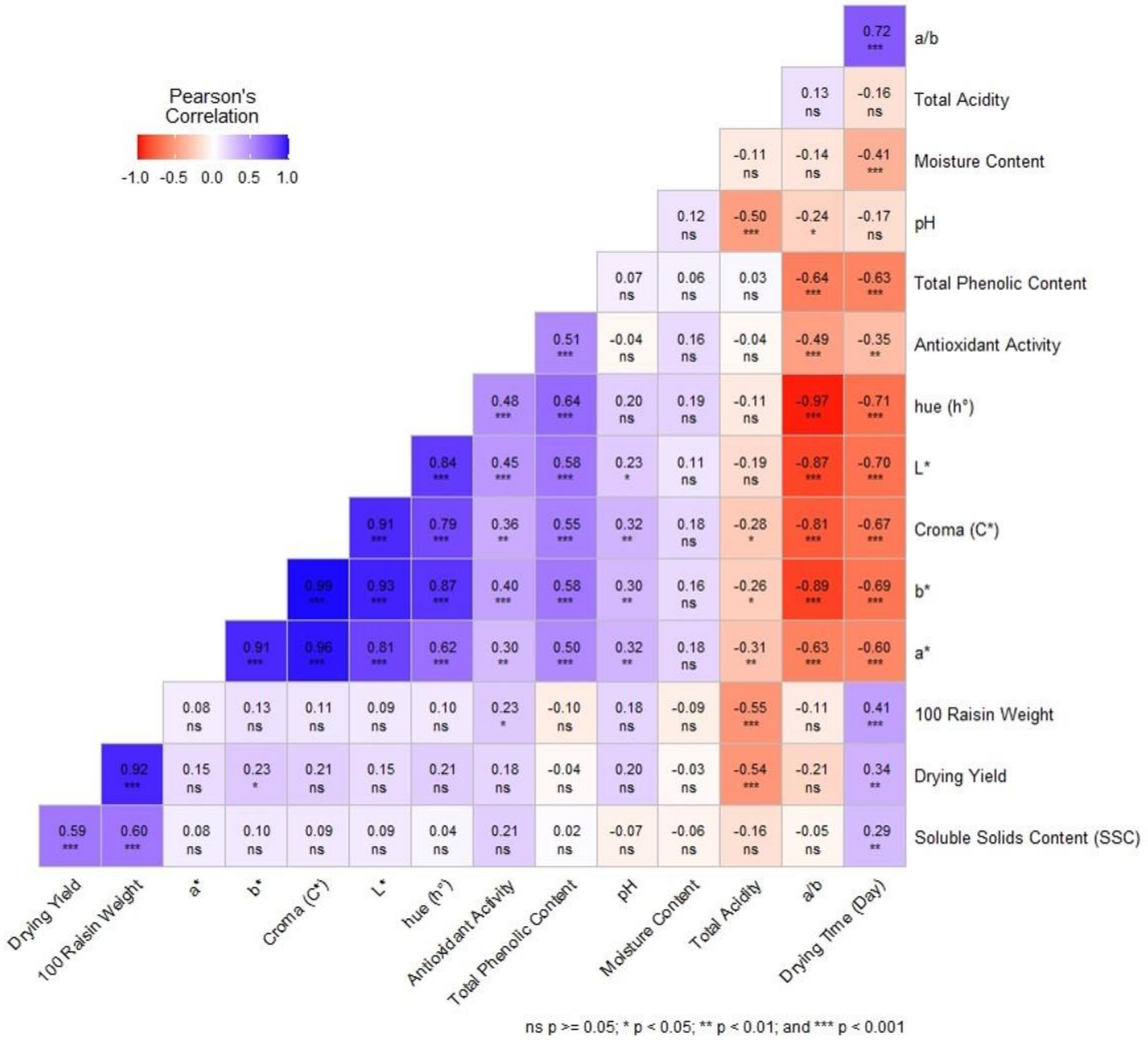


Figure 4- Correlations between variables

4. Conclusions

In this study, a dimension reduction was made by PCA on 15 variables being drying characteristics and raisin quality. According to this analysis, 15 variables were reduced to four principal components with an explainable variance ratio of 82.1%.

Subsequently, NLPCA was performed to determine the relationship of the four principal components with the pre-treatment solutions and varieties. As a result of the analysis, six variables consisting of variety, pre-treatment solution, and four produced variables (PC1, PC2, PC3, and PC4) were reduced to two dimensions with an explainable variance ratio of 64.0%. Thus, the linear and/or non-linear relationships between a total of 19 variables, consisting of two varieties, 13 pre-treatment solutions, and the first four principal components, were reduced to a two-dimensional space and presented visually in an easy to understandable and interpretable way. It was determined that the pre-treatment solutions were effective on L^*, a^*, b^*, chroma (C^*), hue (h°), a/b values, antioxidant activity, total phenolic content, and drying time constituting PC1. It was remarkable that the colour parameters in prominent clusters in cluster analysis were also the parameters forming PC1 in PCA analysis. This shows that the results obtained according to both methods (PCA and NLPCA) supported each other. Similarly, it was determined that the total acidity, SSC, drying yield, 100 raisin weight, drying time, antioxidant activity, and pH value, constituting PC2 and PC3, varied depending on the variety. The best pre-treatment solutions were found to be the "5% K_2CO_3 + 1% Olive oil" solution for the Bineteti variety and the "5% K_2CO_3 + 2% Hazelnut oil" solution for the Zeyti variety. Alternative solutions to these solutions were found to be "5% $NaHCO_3$ + 1% Olive oil", "5% $NaHCO_3$ + 2% Sesame oil", "5% K_2CO_3 + 1% Sesame oil", and "5% K_2CO_3 + 2% Hazelnut oil" solutions for the Bineteti variety and "5% $NaHCO_3$ + 2% Hazelnut oil" solution for the Zeyti variety. It was determined that the pre-treatment solutions recommended for the varieties caused brighter, more vibrant, and yellow-coloured raisins to be obtained, shortened the drying time, and positively affected the total phenolic content and antioxidant activity. According to the correlation analysis, it was determined that the drying time correlated with all variables except pH and total acidity, and the colour parameters correlated with each other, as well as the total phenolic content and antioxidant activity. It was determined that the moisture content did not correlate with any variable except drying time, and the SSC correlated with the drying time, drying yield, and 100 raisin weight, and the drying yield correlated with the drying time, total acidity, and 100 raisin weight.

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