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Gyümölcstárolás során bekövetkező változások nyomon követése korrelatív gyors módszerekkel

Monitoring changes during fruit storage using correlative rapid methods

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ABSTRACT

Apricot is one of the most important stone fruits in the world. Non-destructive techniques, like near infrared (NIR) spectroscopy, are increasingly used to determine the physiological state and quality of such fruits. The aim of the present research was to employ NIR spectroscopy and chemometrics, namely principal component analysis (PCA), linear discriminant analysis (LDA) partial least squares regression (PLSR) to classify apricot fruit based on cultivar, maturity, storage time, and to predict physicochemical attributes, such as firmness, L^* a^* b^* values, normalized difference vegetation index (NDVI), normalized anthocyanin index (NAI), soluble solid content (SSC) and pH. Classification models by cultivar, maturity, and storage time showed varying accuracy. L^* , b^* , and pH values could be predicted with PLSR using NIR, when the R_{cv}^2 and RMSECV values were between 0.36-0.54 and 0.59-3.42, respectively. The developed models require further optimization with wider natural variability of the fruits and higher sample numbers.

Keywords: Apricot, physicochemical properties, NIR spectroscopy, chemometrics

1. INTRODUCTION, PROFESSIONAL BACKGROUND

Apricot is an important stone fruit with an annual production of 3.8 million tons [1]. The most cultivated apricot varieties belong to *Prunus armeniaca* L. It satisfies the latest nutritional trends due to its moderate energy, high dietary fiber, antioxidant and mineral content. Consumers prefer high-quality, flavor-rich varieties, and the sugar-acid ratio of which is one of the most important characteristics, besides firmness and attractiveness [2]. In the determination of the physiological state and physicochemical traits of fruits, the use of methods that examine samples as a whole in a “fingerprint” approach, is widespread, thereby, determination and intervention can come to fruition in a fast, non-destructive and even on-the-spot manner [3]. Near-infrared (NIR) spectroscopy in combination with chemometric methods has been used effectively to predict fruit quality, namely soluble solid content, titratable acidity, firmness [4], skin color [5,6] and also to discriminate sweet and non-sweet nectarines [7] and to predict the days before decay of peach [8].

2. AIMS

The aim of the research was to develop correlative models that contribute to the rapid and accurate determination of certain physicochemical attributes of apricots of different varieties, different ripening stages and batches of apricots stored for different periods of time.

3. MATERIALS AND METHODS

3.1. Test samples

Different varieties of apricots (*Bergeron*, *Bergerouge*, *Zebra*) were used in the investigations. The fruits were of different maturity stages on the time of harvest (tendering, ripe for consumption and ripe for processing). The fruits were analyzed on the day of harvest and the group of ripe for processing were subjected to analysis after one and two weeks of storage. A total of 25 fruits per variety were examined using five fruits per each treatment group resulting in a total of 75 fruits.

3.2. Determination of physicochemical properties

Among the physical parameters, firmness and CIE L^* a^* b^* values were measured, normalized difference vegetation index (NDVI) and normalized anthocyanin index (NAI) were also specified. Among the chemical traits, soluble solid content (in °brix) and pH were determined. The mentioned tests were performed twice on each fruit, on the greener and redder sides.

3.3. Near infrared spectroscopic analysis

The spectral data were collected in the wavelength range of 1000–2500 nm with an PMC Spectralyzer 10-25 infrared spectrophotometer. Each sample was measured three times, once on the greener side, once on the redder side and once on cut fruit surface.

3.4. Data analysis

Before actual data analysis, the recorded NIR spectra were pretreated between 1000–1600 nm with Savitzky-Golay smoothing filter (2nd order polynomial, 13 points), the pretreatment was further optimized by the following methods: multiplicative scatter correction (MSC), standard normal variate (SNV), 1st or 2nd derivative using the Savitzky-Golay filter with 2nd order polynomial and 13 or 17 points. Principal component analysis (PCA) was employed to detect outliers and to reduce the initial data matrix. Linear discriminant analysis (LDA) models were built for classification according to apricot varieties, maturities, and storage time. Partial least squares regression (PLSR) models were developed to predict the aforementioned physicochemical parameters by measurement sides. The models were tested with leave-one-out validation. The PLSR

model fit was described by the coefficients of determination (R^2) and the root mean square error (RMSE) during model calibration (C) and validation (CV).

4. RESULTS AND DISCUSSION

In terms of the accuracy of the LDA models, the combination of Savitzky-Golay smoothing (2nd order polynomial, 13 points) and 1st derivative (2nd order polynomial, 13 points) pretreatments proved to be the most efficient. In these cases, the average correct classification of the apricot varieties was 75 and 68.87% in recognition and prediction (Figure 1a). The classification accuracies of fruit maturity were between 68.35-88.36% for model building and 33.3-56.66% for validation, by cultivar (Figure 1b). Misclassification was mostly in the case of *Zebra* cultivar. For different cultivars, the storage time was distinguished by LDA with 78.32 to 100% accuracy during model construction, and with 76.78 to 83.4% accuracy during validation (Figure 1c).

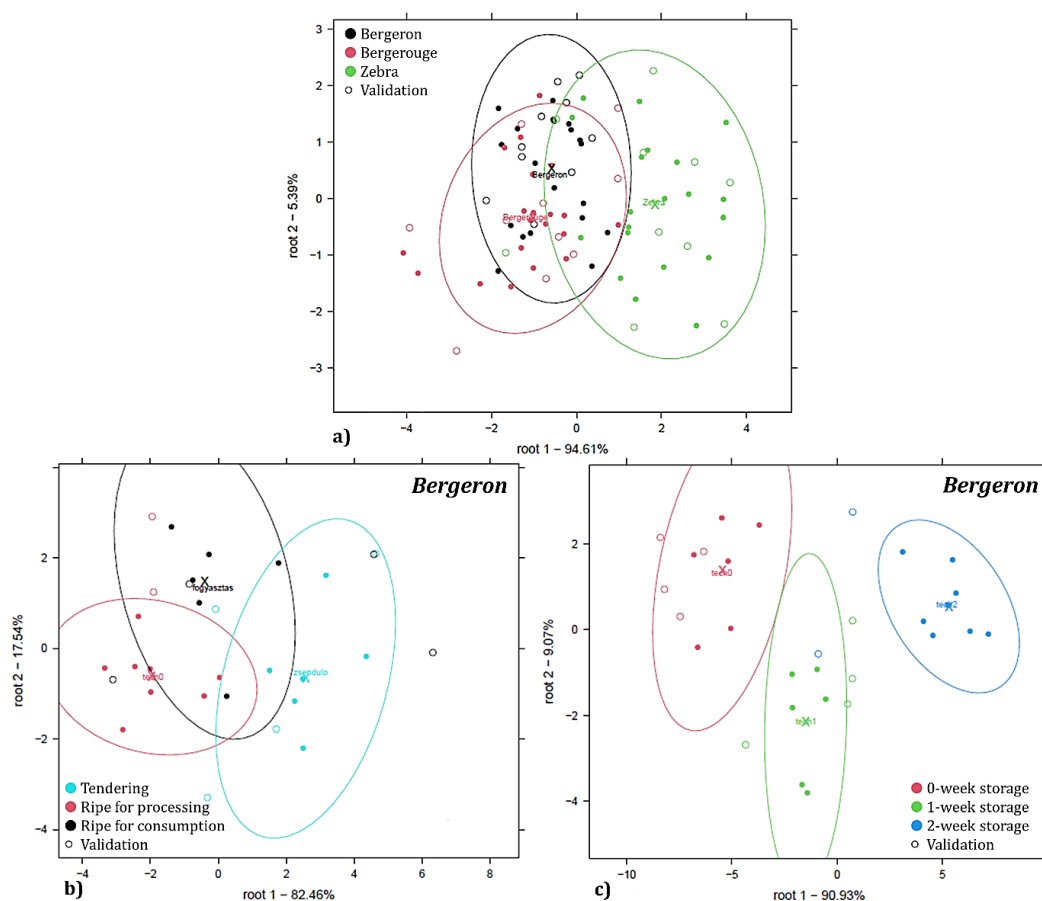


Figure 3. LDA classification of the fruit samples using their NIR spectra based on a) apricot variety; b) fruit maturity; c) storage time

The PLSR models developed to predict various physicochemical parameters of apricots performed rather poorly. In general, L^* , b^* , and pH values could be estimated, when the R_{CV}^2 and RMSECV values were between 0.36-0.54 and 0.59-3.42, respectively (Table 1). The pH could be estimated from all sides (greener, redder, greener + redder, cut surface),

but most accurately from the cut fruit surface with 1st derivative (2nd order polynomial, 17 points) pretreatment.

Table 2. NIR spectroscopy-based PLSR prediction of some selected physicochemical parameters of apricot

Property	Measurement side	Components	R _c ²	RMSEC	R _{cv} ²	RMSECV	N
L*	Redder	3	0.48	3.16	0.39	3.42	75
b*	Redder	3	0.45	2.92	0.36	3.16	75
pH	Cut surface	10	0.76	0.43	0.54	0.59	75

R_c², R_{cv}² — Coefficient of determination of model calibration and cross-validation; RMSEC, RMSECV — Root mean square error of model calibration and cross-validation; N — Sample count

5. CONCLUSION

The study aimed to construct LDA and PLSR models on NIR spectra of apricots to predict apricot cultivar, maturity, storage time and numerous physicochemical quality attributes. According to prior publications, NIR spectroscopy is suitable for conducting such research. After multiple spectral pretreatments, NIR spectroscopy proved to be effective in classification. The parameter estimation PLSR models performed rather feeble, this can be explained by the relatively low natural variability of the tested fruits and the small sample number. However, based on our experimental results, further optimization is required, both in experimental design and data evaluation.

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