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Content:

Multi-spectral assessment of ingredients and physical properties of apricot

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Introduction

Some quality-related internal parameters of apricot can be predicted by the reflected NIR spectrum. According to the recent publications[1,2], using 800-2500nm range, the soluble solids content (SSC) and the titratable acidity (TA) can be predicted properly, but other quality traits, like malic and citric acid, individual sugars, ethylene production and firmness were not satisfactory modeled.

The non-destructive, non-contact and fast optical measurement methods, like hyper- or multispectral imaging are more and more demanded for on-line industrial quality control tasks. These methods combine the advantages of spectroscopy and conventional image processing, obtain the spatial distribution of spectral properties on non-homogeneous surfaces, but have much less spectral information in usually noisy environment.

For testing the feasibility of multispectral industrial application, the internal-, rheological and optical properties of apricot cultivars were investigated. Samples of three cultivars, three ripening state and three further categories by storage time were measured with 20 samples in each group. All the measurements were taken on both blushed and un-blushed side as well.

The optical properties were measured and checked in different spectral ranges with different instrumentation. Mechanical properties of the samples were measured on dynamical way, with two impact methods and an acoustic response system. The chemical properties were measured after all non-destructive methods mentioned above.

Materials and Methods

In the experiment described below, samples of Bergeron, Bergarouge and Zebra apricot cultivars were tested grouping in three ripeness category (1. immature, 2. ripened for processing, 3. ripened for consumption). The second category was stored for one week (4. category) and two weeks (5. category). The mass (m) and the three perpendicular diameters (d_1, d_2, d_1) were recorded. The following optical, mechanical and chemical parameters were inspected:

- Optical: RGB imaging system, Pygment analyzer, ColorLite sph850 spectrophotometer, PCM Spectralyzer 10-25, NIR Multispectral Imaging System
- Mechanical: acoustic resonance method, impact method, Sinclair Internal Quality Tester
- Chemical: pH, SSC (Brix), sugar-content (fructose, glucose, saccharose, xylose, raffinose), free acid content

The correlation between **NIR spectrophotometer measurement** and different quality traits was investigated by Partial Least Squares (PLS) linear regression method. Since randomly selecting two third of whole dataset as calibration subset did not resulted reliable prediction, finally the first (immature) and third (ready for consumption) groups were used as calibration set having a wide distribution of internal properties. The optimal number of latent variables was determined on the base of the minimal value of RMSEV and the maximal value of Relative Performance Determinant (RPD). The overfitting of regression was checked by the Beta-vector.

The **multispectral images** were segmented, than the average spectra of investigated area were compared with spectrophotometer measurements. The prediction model was the PLS method as well. Multi-linear regression (MLR) method was used to determine the significant wavelengths of given internal properties. All, the statistical algorithm were developed in Mathcad software package (version 14.0, MathSoft, USA).

Results

All the measured optical (e.g. Lab, NDVI, NAI) and mechanical (Sinclair-, impact- and acoustic stiffness) parameters were changed monotonically by the ripeness state and by the storage time as well. The chemical properties, however, behave irregularly. The **pH** increased during ripening, but during storage, it grown significantly at the first week, then slightly decreased. The SSC (**Brix**) increased during ripening, but has not changed by the storage time. The change of **sugar-content** (fructose, glucose, saccharose, xylose, raffinose) and **titratable acid** (TA) was not commonly monotonous by ripeness state, neither by storage time. This paper will focus on the prediction of pH and Brix.

1. Spectrophotometer data analysis:

The general profile of the absorption spectra was dominated mostly by water absorption bands with bands at 970, 1190, 1450 nm and 1940 nm. The changes of absorption spectra were monotonous ether by ripeness state or by storage time on all cultivars and on all side (blushed and un-blushed) of samples.

a) The PLS prediction model of pH resulted LV=3 as optimal number of factors. At this value, the RMSEV had the minimum and RPD had a maximum simultaneously. The vector B-coefficients was found to be smooth enough, reporting, that there was no overfitting. The RMSEV=0.24 value of validation was small enough again compared to the deviation of pH values of sample set. Both the value of RPD=2.45 and the value of determination coefficient (R^2=0.58) show good correlation between NIR spectra and the pH of apricot (Figure 1).

b) The PLS model of Brix resulted the LV=3. The Beta-vector showed no overfitting. The value of RMSEV=1.22 was promising compared to the deviation of Brix on sample set. Despite of the RPD=1.58 is smaller, the R^2=0.58 showed encouraging correlation again.

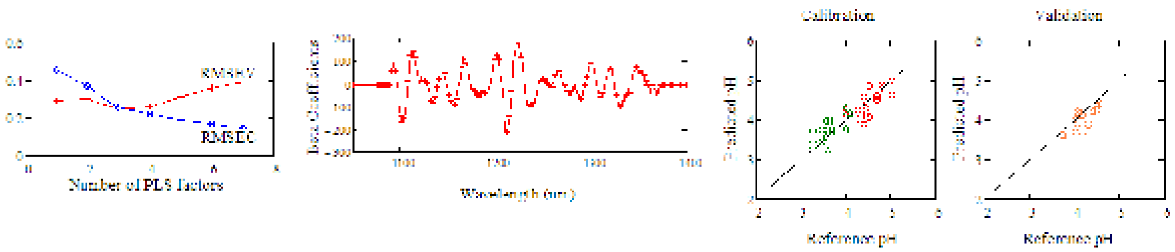

Figure 1: Spectralyzer model: A.) RMSEV B.) B-vector. C.) Sample set

2. Multispectral data analysis:

The frames, acquired through different filters, were processed for segmenting areas to be investigated. The average of reflection was calculated for each image using 12bit (0..4095) resolution. The relation between NIR absorption measurements and multispectral reflection data was found to be satisfactory. The changes of reflected spectra were also monotonous ether by ripeness state or by storage time on all cultivars and on all side of samples.

c) Using multiplicative scatter correction, with LV=5 factors, the RPD=1.73 and the small RMSEV=0.27 show acceptable relation. R^2=0.24 is small, because the cultivars have different behaviour on these wavelengths. Building the model for given cultivar (e.i. Bergeron), the results were better. Without multiplicative scatter correction, LV=2 factors resulted RPD=1.38 and RMSEV=0.37 values. The significant wavelengths have been calculated by MLR method.

d) The model of Brix resulted the LV=6 as optimal number of latent variables. The value of RPD=1.20 is barely bigger than 1, RMSEV=1.52 is acceptably small, but the determination coefficient is almost zero, signing that using these wavelengths, the soluble solids content can not be predicted. Significant wavelengths of this property must be studied by hyperspectral method.

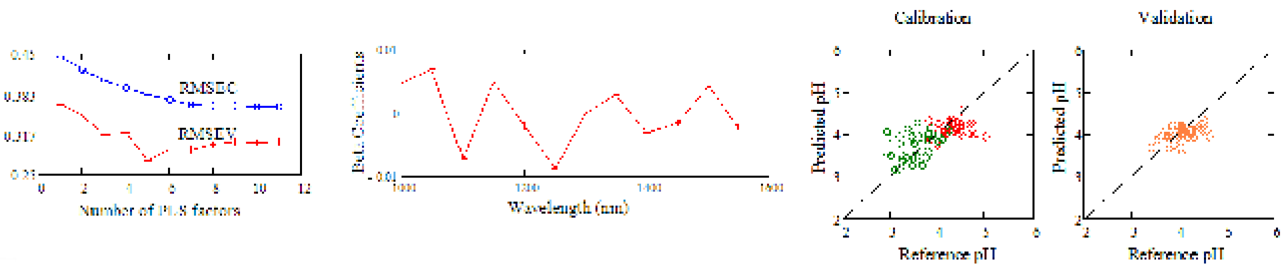

Figure 2: Multispectral model: A.) RMSEV B.) B-vector. C.) Sample set

Conclusion

The multispectral assessment of ingredients seems to be encouraging, but:

- Set of samples must be selected for calibration, having wider range of properties.
- All the noise, stray light should be especially excluded at measurements.
- More chemical factors should be measured to explain the irregular changes of sugar and acid components (internal standard addition).
- Significant wavelengths of investigated properties will be studied by hyperspectral method.
- Image processing algorithm will be developed to segment blushed and un-blushed areas on multispectral images to improve efficiency.

References

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