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Real-time monitoring of apples (*Malus domestica* var. Gala) during hot-air drying using NIR spectroscopy

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Objectives

Among commercial fruits, apple shows a growing trend to its worldwide consumption, where dried apple plays a major part in food industry as raw material to produce snacks, integral breakfast foods, chips, etc., which have become popular in the diet of modern consumers in parallel with the human consumption of organic products. Despite apple tissue exhibits extensive and non-homogeneous discoloration during drying, it is nowadays often dried by conventional methods which, however, are usually uncontrolled and then prone to product quality deterioration. However, because no all conventional drying treatments are allowed by the European Organic Regulation (i.e. EC No. 834/2007 and EC No. 889/2008), drying of organic apples should be carefully optimized to obtain comparable results to conventional methods. Therefore, the main objective of the proposed study was to investigate the feasibility of near-infrared (NIR) spectroscopy as smart drying technology to proactively and non-destructively detect and monitor quality change in organic apple wedges during hot-air drying.

Methods

Organic apples (*Malus domestica* B. var. Gala) were purchased from a local organic trader and stored at 4±1°C until processing. Apple wedges, without core and peel, were prepared by washing and cutting fruit into discs (5-mm thick) and subsequently cutting each disc into quarters. Samples were subjected to 8-h hot-air drying and batch sampling was performed from 0 to 8 h drying with steps of 1 h. Each batch was subjected to both NIR spectral data acquisition (range 1100-2300 nm, 2-nm resolution) and determination of CIELab color, moisture content, water activity, soluble solids content, titratable acidity and pH. PLS (partial least squares) regression models were computed to changes in state variables, while PLS-DA (partial least squares discriminant analysis) was used to assign each apple wedge to a specific dehydration phase based on its spectral profile. Interval PLS (iPLS) and PLS-DA (iPLS-DA) algorithms were also used to perform feature selection with the aim of reducing the number of wavelengths of each prediction model.

Results

The feasibility of using NIR spectroscopy as an automated, non-destructive and rapid method to measure state variables of apple wedges during drying was demonstrated. PLS models showed excellent performance metrics for moisture ($r^2 = 0.98$), water activity ($r^2 = 0.97$), chroma ($r^2 = 0.85$) and soluble solids content ($r^2 = 0.96$) prediction. PLS-DA models allowed recognition of drying phases with an total accuracy of 96.03%. Both regression and classification models based on few wavelengths (i.e. iPLS and iPLS-DA, respectively) showed metrics comparable to models obtained from the full spectrum.