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Using absorption and reduced scattering coefficients for non-destructive analyses of fruit flesh firmness and soluble solids content in pear (*Pyrus communis* 'Conference')—An update when using diffusion theory

Segun Emmanuel Adebayo[a,b,e], Norhashila Hashim[a], Roland Hass[c], Oliver Reich[c], Christian Regen[b], Marvin Münzberg[c], Khalina Abdan[a], Marsyita Hanafi[d], Manuela Zude-Sasse[b,*]

[a] Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, Malaysia
[b] Department of Horticultural Engineering, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB) 14469 Potsdam-Bornim, Germany
[c] Physical Chemistry – innoFSPEC, Institute of Chemistry, University of Potsdam, Am Mühlenberg 3, 14476 Potsdam-Golm, Germany
[d] Department of Computer and Communication Engineering, Universiti Putra Malaysia, Malaysia
[e] Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria

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ABSTRACT

Quality attributes of fruit determine its acceptability by the retailer and consumer. The objective of this work was to investigate the potential of absorption (μ_a) and reduced scattering (μ_s') coefficients of European pear to analyze its fruit flesh firmness and soluble solids content (SSC). The absolute reference values, μ_a^* (cm^{-1}) and $\mu_s'^*$ (cm^{-1}), of pear were invasively measured, employing multi-spectral photon density wave (PDW) spectroscopy at preselected wavelengths of 515, 690, and 940 nm considering two batches of unripe and overripe fruit. On eight measuring dates during fruit development, μ_a and μ_s' were analyzed non-destructively by means of laser light backscattering imaging (LLBI) at similar wavelengths of 532, 660, and 830 nm by means of fitting according to Farrell's diffusion theory, using fix reference values of either μ_a^* or $\mu_s'^*$. Both, the μ_a^* and the μ_a as well as $\mu_s'^*$ and μ_s' showed similar trends. Considering the non-destructively measured data during fruit development, μ_a at 660 nm decreased 91 till 141 days after full bloom (dafb) from 1.49 cm^{-1} to 0.74 cm^{-1} due to chlorophyll degradation. At 830 nm, μ_a only slightly decreased from 0.41 cm^{-1} to 0.35 cm^{-1}. The μ_s' at all wavelengths revealed a decreasing trend as the fruit developed. The difference measured at 532 nm was most pronounced decreasing from 24 cm^{-1} to 10 cm^{-1}, while at 660 nm and 830 nm values decreased from 15 cm^{-1} to 13 cm^{-1} and from 10 cm^{-1} to 8 cm^{-1}, respectively. When building calibration models with partial least-squares regression analysis on the optical properties for non-destructive analysis of the fruit SSC, μ_a at 532 nm and 830 nm resulted in a correlation coefficient of R = 0.66, however, showing high measuring uncertainty. The combination of all three wavelengths gave an enhanced, encouraging R = 0.89 for firmness analysis using μ_s' in the freshly picked fruit.

1. Introduction

Pears (*Pyrus communis* L.) are a sweet fruit with melting texture when fully ripe. Pears are widely consumed in the world (Faostat, 2016) and are required to meet quality standards when traded. These requirements involve external appearance and internal quality traits such as fruit flesh firmness, pigments, titratable acidity, pH, and soluble solids content (SSC). Firmness and SSC have been widely used to determine fruit maturity and eating experience in fruits in general. Particularly in pears no thresholds can be given due to high variability with many consumer preferring soft pears (Vangdal, 1982), while also crisp fruits are demanded at present and the combination of firm and juicy was pointed out in own sensory panels (unpublished data). However, retailers request firm fruit, while the OECD standards demand fruit that are getting mature instead of ever green pears. For marketing, it would be desirable to grade pears inline addressing different customers with consistent produce.

Various non-destructive spectral-analytical methods have been used to determine these quality traits in pear and were reviewed recently for fruit in general and applied for pear analysis in particular: Methods include spectroscopy in the visible and shortwave near infrared wavelength range (Nicolai et al., 2007; Cen and He, 2007; Cavaco

* Corresponding author.
E-mail address: mzude@atb-potsdam.de (M. Zude-Sasse).

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