Quality assessment of kiwi by means of laser-induced backscattering imaging

Qualitätsbewertung von Kiwifrüchten auf der Basis eines bildgebenden Verfahrens zur Messung der laserinduzierter Rückstreuung im Fruchtgewebe

László Baranyai[1], Zhaoshen Qing[1,2], Manuela Zude[1]
[1] Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB), Max-Eyth-Allee 100, 14469 Potsdam-Bornim, Germany, e-mail: zude@atb-potsdam.de
[2] China Agricultural University (CAU), College of Food Science and Nutritional Engineering, Qinghua Donglu No.17, 294#, 100083, Haidian District, Beijing, P.R. China

Abstract: The internal quality parameters, such as soluble solids content (SSC) and fruit flesh firmness, are key features in postharvest processing and management of the supply chain from field to fork. The nondestructive determination of these attributes is essential for real-time measurements. Acoustic and impact techniques, near-infrared spectroscopy in the range of 600-1100nm are reported to be successful in quality control. A new approach of the analysis of laser-induced backscattering is introduced in this work. The size of the fruit is calculated on the basis of the displacement of the spot on the surface. The intensity profile is created as function of distance measured from the incident point of the laser beam. The main goal of the presented study is to find the proper parameters of the intensity profile of the laser light backscattering in order to estimate firmness. The backscattering area is estimated using the distance of the inflection point, and the change of the profile is described with an exponential function. The experiments are started but the research work is in its very early stage, therefore preliminary results are shown here.

Keywords: kiwi quality, imaging, laser-induced light backscattering, nondestructive sensing

Zusammenfassung: *Daten zu inneren Qualitätsparametern von Früchten, wie der lösliche Trockensubstanzgehalt und die Fruchtfleischfestigkeit, sind essentiell für das Prozessmanagement entlang der Versorgungskette vom Feld bis zum Verzehr. Für deren prozessnahe Erfassung eignen sich besonders zerstörungsfreie Methoden. Akustische und mechanische Messmethoden sowie die Reflexionsspektroskopie im nahinfraroten Wellenlängenbereich zwischen 600-1100 nm haben sich für die Analyse einzelner Parameter bereits in der Qualitätskontrolle bewährt. In der vorliegenden Arbeit soll ein neuer Ansatz zur kombinierten Erfassung der beiden genannten Fruchtqualitätsparameter auf der Basis von bildgebenden Verfahren zur Messung der laserinduzierten Rückstreuung vorgestellt werden. Hierbei wurde die Fruchtgröße auf der Basis der Abweichung der Laserreflexion auf der Oberfläche bestimmt. Die Intensitäten des rückgestreuten Lichtes als Funktion der Distanz vom Einstrahlpunkt in das Fruchtgewebe ergab charakteristische Verteilungsprofile. Die Analyse dieser Histogramme erfolgte mittels des ersten Wendepunktes sowie der Koeffizienten einer Exponentialfunktion. Der Zusammenhang zwischen Koeffizienten und Gewebeeigenschaften sind im Beitrag dargestellt.*

Deskriptoren: *Kiwiqualität, Bildverarbeitung, laserinduzierte Rückstreuung, zerstörungsfreie Analyse*

1 Introduction

There are internal quality parameters of outstanding importance in postharvest processing of fruits and vegetables, and also in the management of the logistics of food and raw materials, such as soluble solids content (SSC) and flesh firmness. Digital image processing applications are able to determine the ripeness stage of certain fruits and vegetables on the basis of their surface pattern (BARANYAI & SZEPES 2002). Nondestructive techniques are already used to measure firmness evolution during storage by means of acoustic and impact methods (DIEZMA-IGLESIAS *et al.* 2006). Due to the increasing uncertainty of the climacteric samples, it is recommended to perform firmness measurements for grading and sorting as soon as possible after harvest (DE KETELAERE *et al.* 2006).

Near-infrared spectroscopy in the wavelength range of 600-1100nm was proved to be able to distinguish between different values of SSC (MILLER & ZUDE 2004). This technique is already built into commercial fruit sorting equipments. There are also good results with analysis of laser-induced backscattering images in order to estimate fruit flesh firmness and SSC in apples (PENG & LU 2006, QING 2007). The backscattering area is segmented in the process and the intensity profile of the spot is investigated in that case. Due to the curvature of the fruit, intensity values should be corrected using the Lambertian cosine law (QING 2007). The histogram of intensities (QING 2007) and the size of the backscattering area (PENG & LU 2006) and the coefficients of the function fitted to the trend of intensity change in radial directions measured from the center of the spot (PENG & LU 2006) have good correlation with the reference values measured with standard methods.

The objective of the presented work is to analyze laser-induced backscattering images of kiwi fruit in order to estimate the firmness. It is also a goal of this study to find a more robust way to describe backscattering area and the profile of intensity values as function of distance measured from the incident point of the laser beam.

2 Materials and methods

Laser beams of selected wavelengths, in the range of 500-1100nm, are steered to the given position of the target point (**Figure1**). The camera is placed above the sample and the incident angle of the laser light is 15°. Color images of 768x576 pixel size and 24 bpp color depth are acquired. The measured intensity of the backscattering area and the position of the spot are affected by the curvature of the fruit. The radius of the fruit is estimated from the same image.

According to the basic rule of the central and perimeter angles of view (eq. 1a.), radius can be estimated on the basis of the displacement of the incident point (d) and the incident angle (α) of the laser beam (eq. 1b). The error of the estimation depends on the accuracy of the setup of the incident angle and the resolution of the image.

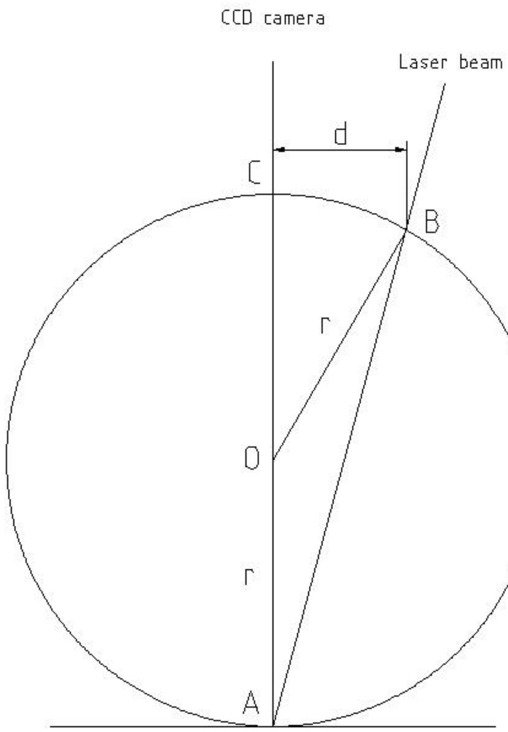


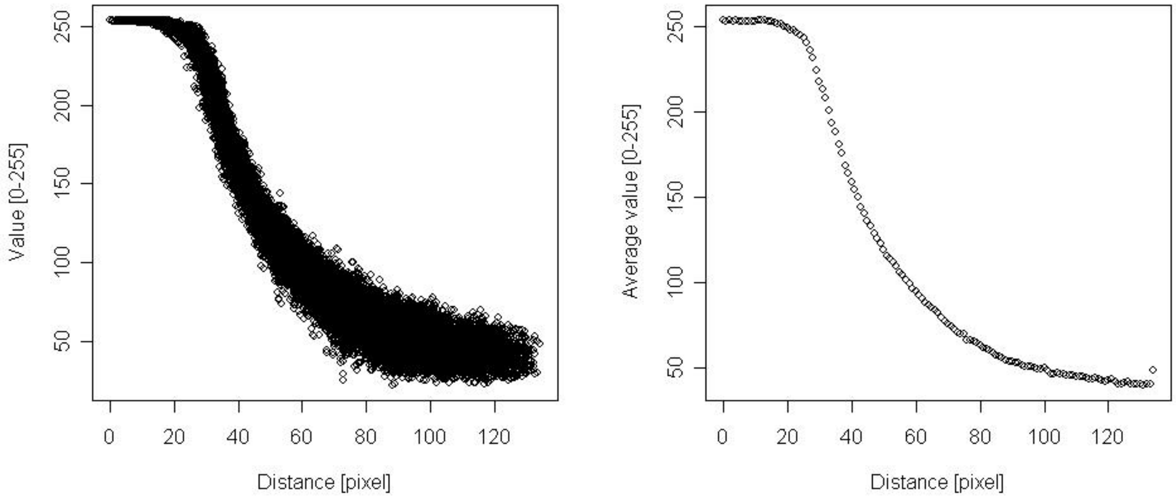
Figure 1: Geometry of the measurement. A = target point, B = incident point, d = displacement of the spot, r = radius

2×CAB∠ = COB∠ a) $r = \frac{d}{\sin 2\alpha}$ b) (1)

First of all, the central point of the spot is calculated. A new layer of luminance is created where the area of the spot is segmented and the central point is given as an average with the weights of luminance values. The Lambertian cosine law is used to adjust the intensity values of the surface. The size of the selected bounding box of the spot is increased so that the darker backscattering pixels can be taken into account as well. Average values of intensity are calculated in radial directions (**Figure 2**). The distance value of zero corresponds to the central point of the spot. The intensity values are decreasing similar to a logistic function of the distance. The inflection point is identified as the position of the maximum value of the first derivatives. This point defines the width of the spot. The initial part of the profile, where distance values are lower than the distance of the inflection point, is eliminated. The slope of the function is calculated with curve fitting (eq. 2.) using the least squares method. The coefficient *C* shows the exponential decrease of backscattering, *A* means the intensity of the incident point, *B* means the intensity change of the profile, *Y* is the estimated value of intensity and *x* is the distance.

$$Y = A - B(1 - e^{-\frac{x}{C}}) \quad (2)$$

This exponential function is fitted to the data points well, with the $R^2>0.99$ (n=106 for **Figure 2b**).



a.) b.)

Figure 2: Profile of intensities in radial directions (a) and the average of concentric sectors (b)

Figure 3 shows the result of curve fitting, the estimated intensities versus the observed intensity values.

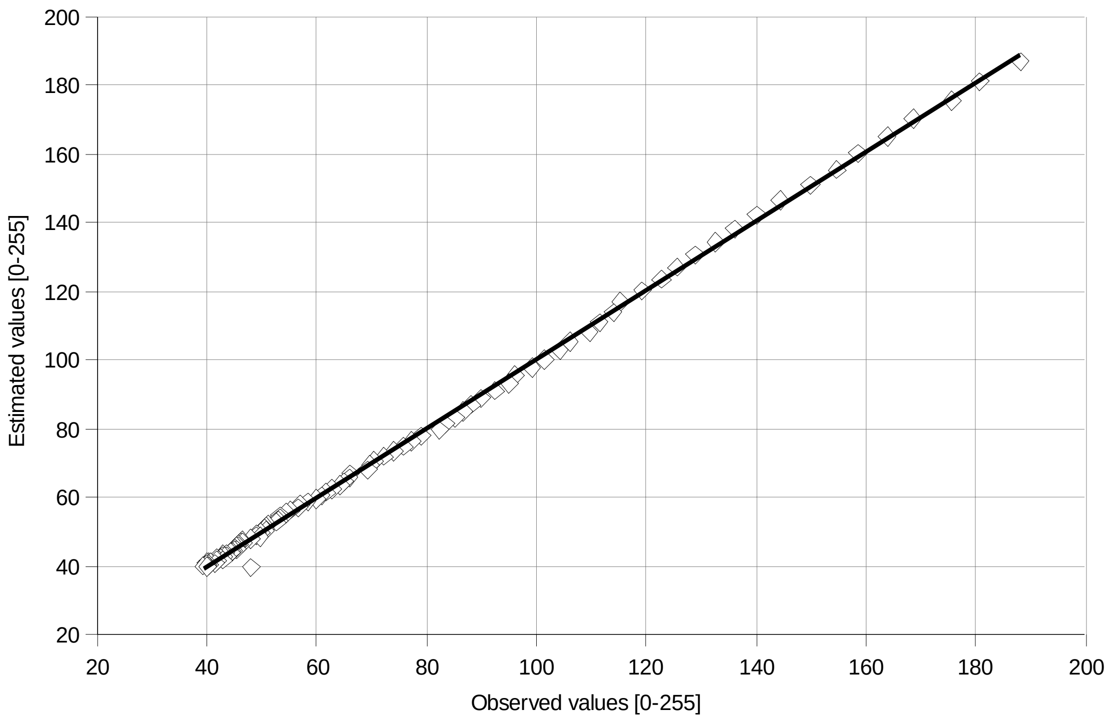


Figure 3: Measured and estimated values of the intensity profile

As a result, there are two parameters suggested to describe backscattering profile:

- the distance between the inflection point of the profile and the incident point of the laser beam
- the exponential decrease of intensity values.

3 Results and discussion

The presented work is in the very early stage of the experiments and has only preliminary test results. At this point, according to these results and the cited papers, only the measurements and data collection were started. Several tests, with statistical analysis, should be performed to answer the questions of

- what are the beneficial wavelengths of the laser beam for quality assessment of kiwi
- what functions are able to estimate the firmness of fruits on the basis of the parameters of the scattering profile
- what other parameters could be extracted from the intensity profile of backscattering
- what optimization can be done to increase the speed of calculations so that it could be built into a sorting line

4 References

BARANYAI L., SZEPES A. (2002): Analysis of fruit and vegetable surface color. Machine Graphics and Vision Journal. 11:351-361

DIEZMA-IGLESIAS B., VALERO C., GARCÍA-RAMO F.J., RUIZ-ALTISENT M. (2006): Monitoring of firmness evolution of peaches during storage by combining acoustic and impact methods Journal of Food Engineering. 77:926-935

DE KETELAERE B., HOWARTH M.S., CREZEE L., LAMMERTYN J., VIAENE K., BULENS I., DE BAERDEMAEKER J. (2006): Postharvest firmness changes as measured by acoustic and low-mass impact devices: a comparison of techniques. Postharvest Biology and Technology. 41:275-284

MILLER W.M., ZUDE M. (2004): NIR-based sensing to identify soluble solids content of Florida citrus. Appl. Eng. Agric. 20:321-327

PENG Y.K., LU R.F. (2006): New approaches of analyzing multispectral scattering profiles for predicting apple fruit firmness and solubles solids content. In: Meeting Presentation of ASABE, Oregon, USA, 9-12 July, Paper № 066234

QING ZS., JI BP., ZUDE M. (2007): Predicting soluble solid content and firmness in apple fruit by means of laser light backscattering image analysis. Journal of Food Engineering. DOI 10.1016/j.jfoodeng.2007.01.016