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Laser Transmission through Vegetative Material

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***Abstract*—**The dynamic speckle or biospeckle is an interference phenomenon generated at the reflection of a coherent light by an active surface or even by a particulate or living body surface. The above mentioned phenomenon gave scientific support to a method named biospeckle which has been employed to study seed viability, biological activity, tissue senescence, tissue water content, fruit bruising, etc. Since the above mentioned method is not invasive and yields numerical values, it can be considered for possible automation associated to several processes, including selection and sorting. Based on these preliminary considerations, this research work proposed to study the interaction of a laser beam with vegetative samples by measuring the incident light intensity and the transmitted light beam intensity at several vegetative slabs of varying thickness. Tests were carried on fifteen slices of apple tissue divided into three thickness groups, i.e., 4 mm, 5 mm, 18 mm and 22 mm. A diode laser beam of 10mW and 632 nm wavelength and a Samsung digital camera were employed to carry the tests. Outgoing images were analyzed by comparing the gray gradient of a fixed image column of each image to obtain a laser penetration scale into the tissue, according to the slice thickness.

***Keywords*—**Fruit, laser, laser transmission, vegetative tissue.

I. Introduction

An important step of the agricultural production system is associated with product inspection and quality evaluation of fruit, vegetable, grains, meat and others. These analyses are generally associated with chemical and biological process, although well developed techniques for some specific products are available and, by other side the major part of agricultural products depend on visual inspection which is based on human interpretation. Seed test is included in the above consideration, since the process depends on the subjectivity of the tetrazoliumtest results. However when the product of interest is represented by fruits, the scientific support for quality inspection is based on tissue mechanical behavior which will generally generate destructive methods. Apple fruit (*MalusdomesticaBorkh*) is of high consumption in Brazil, constituting a very profitable market, emphasizing the varieties named Gala, Fujii which reach American and European markets due to special taste and nutritional value. Several authors [1], [2], [3], had presented scientific reports related to the search of fast as well as non destructive methods applied to quality evaluation of agricultural products. The authors noted a clear tendency toward optical methods and image analyzes associated to computational process, turning feasible automation and data interpretation. Recent literature discloses a group of optical methods based on the biospeckle phenomenon, which plenty satisfy the issues associated to subjectivity and automation possibilities. Laser biospeckle or dynamic speckle is an interference phenomenon which occurs at a coherent light beam incidence on an active surface such as a biological tissue, which results from biological activities. It should be emphasized that the term dynamic speckle refers to a purely physical activity with non biological influence and by the other side the term biospeckle refers to biological activities. Several techniques are reported by the literature to evaluate the biospeckle phenomenon, such as the Moment of Inertia (MI), which was proposed by Arizaga (1999) [4] to quantify the undergoing dynamical process, the Generalized Difference method (GD) and Fujii which has the capability of generating maps of activity to differentiate areas in a same material. Recent studies are reported based on frequency analyzes [5] and entropy analyzes [6] allow a better understanding and domination of the biospeckle methods for further applications in Agricultural Engineering. However the interaction of a laser with biological material is specific for each particular material, being necessary to study a close adjustment generated from these interactions, such as the laser transmission through biological materials. These interactions present peculiar characteristics as the exponential depolarization as the light penetrates the biological tissue [7]apud[1]. However when the reflection is generated from a superficial interaction the polarization is maintained [9]apud [1]. XU et al (1995) [9] stated that it exists a relation between the illuminated area and penetration depth into the vegetative tissue. According to Lambert's Law, emitted light has exponentially decreasing intensity as the absorbing media thickness increases arithmetically, as the Equation 01 represents.

$$I = I_0 10^{-xl} \qquad (1)$$

Where **I** stands for transmitted light intensity, **Io** is the incident light intensity, **x** is a constant named absorption coefficient which depends on the absorbing media and **1** is the absorbing medium thickness. Beer's Law refers to the light transmission according to the soluble material concentration in the medium. The intensity of a monochromatic bean decreases exponentially as the absorbing medium concentration increase arithmetically. Equation 02 express what was explained above.

$$I = I_0 10^{-kc} \qquad (2)$$

Where **I** is the light intensity, **Io** is the incident light intensity, **k** is the coefficient of absorption an **c** is the concentration of

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the absorbing medium. In a 8 bits codified image, the pixels are represented by intensities varying from 0 for the black to 255 to the white. Variations from the white to the black are represented in the image matrix as intermediate values between these two extremes. Based on that, an image of a shining object is represented in the coded in 8 bits it will present elevate gray scale close to 255 and a not so shining object image will be represented by a set of pixels with values close to zero. If the images are captured in identical conditions, pixel intensities differences can be used to compare according to the light quantity reaching the objects through the same medium. Based on what it has been exposed before, the objective of this research work can be identified as to investigate the laser transmission through samples of apple tissue (*MalusdomesticaBorkh*), Fujii variety in order to investigate the interaction between the laser and the apple tissue.

II. Materials and Methods

The experimental phase of this research work was carried at the Laboratory of Optics at FEAGRI, UNICAMP, Campinas, SP, Brazil. The experimental setup included a 632 nm with 10 mW diode laser, a CCD camera, a PC and the ImageJ software for image processing, as shown by the Fig. 1 Apple slices were cut with 4.5,18 and 22 mm thickness.

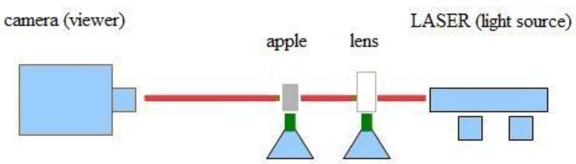


Fig. 1 Experimental setup adopted for the optical test

Captured images were processed and analyzed by comparing the gray gradient of a fixed column of each image to obtain a laser penetration scale into the apple tissue for each slice thickness.

III. Results and Discussions

Table I shows the average light intensity in gray scale of the pixels as function of thickness, including the correspondent standard deviation of each case. Figure 2 exhibits a visual representation of the obtained data.

TABLE I
General Average Value as Function of Apple Sample Thickness

Thickness (mm)	**4**	**5**	**18**	**22**
Average	155,43	152,82	135,7	114,61
Standard Deviation	31,1	23,7	12,47	10,33

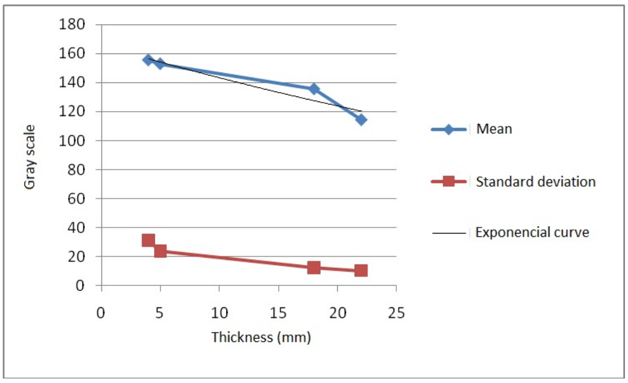
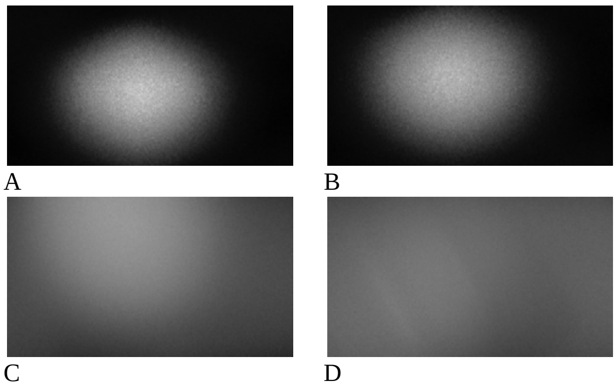
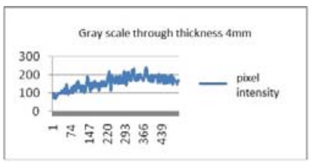


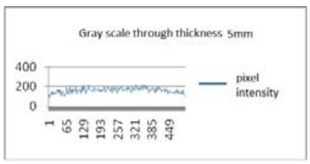
Fig. 2 Average pixel intensity standard deviation variation as function of sample thickness

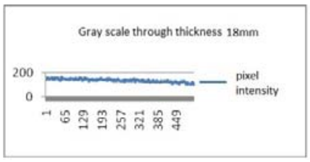
From Table I and from Fig. 2 it can be noted that the average values as well as the standard deviation values decreases exponentially as thickness increase, which is in agreement with Lambert's and Beer's laws and also with the data analyzed by Moreira (2002) [10] for laser transmission in slices of beans (*Phaseolus vulgaris* L.). Pixel intensity decreasing values with increasing slice thickness agrees with expectations, since the large the thickness the lower will be the laser penetration, resulting images with low brightness and consequently represented by low pixel values. The decreasing standard deviation values as function of slice thickness is related to light uniformity during material penetration, since the higher the thickness, the higher the light uniformity passing through the material, resulting lower standard deviation values. The following graphs shows the Gray scale values for a central image line registering light intensity received after crossing Apple slices of different thickness.



Processed Images; thickness A 4mm; B 5mm; C 18mm; D 22mm







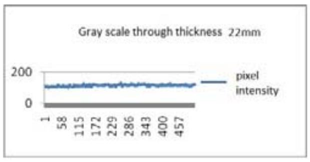


Fig. 3 Gray scale values for one pixel column obtained by the laser transmission trough Apple slices of different thickness (4, 5, 18 and 22 mm)

IV. Conclusion

Obtained results allow to conclude that apple slice thickness with 18 and 22 mm permit laser penetration, though with very reduced intensities as compared with the thickness of a 4 mm and 5 mm, showing that the light transmission varies with the average depth. Future works should consider the penetration quantification as well as the generation of a corresponding equation, for a better interpretation of laser metrology associated to fruits.

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