Biospeckle Supported Fruit Bruise Detection

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***Abstract*—**This research work proposed a study of fruit bruise detection by means of a biospeckle method, selecting the papaya fruit (*Carica papaya*) as testing body. Papaya is recognized as a fruit of outstanding nutritional qualities, showing high vitamin A content, calcium, carbohydrates, exhibiting high popularity all over the world, considering consumption and acceptability. The commercialization of papaya faces special problems which are associated to bruise generation during harvesting, packing and transportation. Papaya is classified as climacteric fruit, permitting to be harvested before the maturation is completed. However, by one side bruise generation is partially controlled once the fruit flesh exhibits high mechanical firmness. By the other side, mechanical loads can set a future bruise at that maturation stage, when it can not be detected yet by conventional methods. Mechanical damages of fruit skin leave an entrance door to microorganisms and pathogens, which will cause severe losses of quality attributes. Traditional techniques of fruit quality inspection include total soluble solids determination, mechanical firmness tests, visual inspections, which would hardly meet required conditions for a fully automated process. However, the pertinent literature reveals a new method named biospeckle which is based on the laser reflectance and interference phenomenon. The laser biospeckle or dynamic speckle is quantified by means of the Moment of Inertia, named after its mechanical counterpart due to similarity between the defining formulae. Biospeckle techniques are able to quantify biological activities of living tissues, which has been applied to seed viability analysis, vegetable senescence and similar topics. Since the biospeckle techniques can monitor tissue physiology, it could also detect changes in the fruit caused by mechanical damages. The proposed technique holds non invasive character, being able to generate numerical results consistent with an adequate automation. The experimental tests associated to this research work included the selection of papaya fruit at different maturation stages which were submitted to artificial mechanical bruising tests. Damages were visually compared with the frequency maps yielded by the biospeckle technique. Results were considered in close agreement.

***Keywords*—**Biospeckle, papaya, mechanical damages, vegetable bruising.

I. Introduction

PAPAYA fruit (*Carica papaya*) is of high nutritional value, since it is considered an outstanding source of vitamin A, vitamin C and calcium. The enzyme named papain is of major industrial interest which is associated to cosmetics, pharmaceuticals being considered very important to the domestic as well as to the international market [1].

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Papaya is a fragile and sensible fruit, very susceptible to mechanical bruising generated during packing process and also by the mechanical handling since harvesting up to the commercialization [2].

Since papaya is consumed *in natura* the presence of bruising should be forcibly avoided. Bruising is quite frequently associated to fungi and other diseases which reduce fruit quality as well as its shelf life.

Bruise detection is normally carried through visual inspection, which is a time demanding and subjective process. The development of new technologies for bruise detection would also allow automation for inspection and selection.

Based on these considerations this research work had as objective to employ a biospeckle technique to detect fungi attacks on papaya fruit flesh, considering the proposed method to be of non invasive character.

Biospeckle methods are based on the interference phenomenon of coherent light when reflected by an active surface. The pertinent literature [3], [4], [7], [8], [9], [10] presents several techniques to evaluate the biospeckle method, including the Moment of Inertia which is able to quantify the phenomenon. The Generalized Difference and Fujii methods can generate activity mapping of the surface under study [11], [12], [13], [14], [15], [16], [17].

Bruised vegetative tissue shows different levels of biological activity when compared with healthy tissues. So, the biological activity variation throughout the tissue surface can be mapped. Braga Jr (2000) [6] states that the Generalized Difference method is able of differentiating activity levels which are associated to the observed speckle pattern changes. The author summarized the method as :“ This method is based upon the obtained image processing of an illuminated surface, identifying the light intensities of each pixel which composes the image expressed as **I(x,y)** where **x** and **y** stand for image coordinates. So, a summation of intensity differences of an image and its subsequent one [6]. Resulting image will show clear pixels associated to intensity changes, as presented by Equation 1.

$$DG(x,y) = \sum_{k=1}^{N} \sum_{l=1}^{N} I_k(x,y) - I_{k+l}(x,y) \qquad (1)$$

Where **I** is the image, **x** and **y** are their points, **k** and **l** are stands for the images, **DG(x,y)** represents a matrix generated after comparing each image with subsequent.

Based on the above considerations the biospeckle technique was selected by this research work to differentiate bruised tissue from the healthy ones.

II. Materials and Methods

The experimental part of this research work was carried in the Laboratory of Optics of the Faculty of Agricultural Engineering, UNICAMP, Campinas, SP, Brazil. Selected papaya sample showed bruises caused by fungi attacks which

Fig. 1 Bruises in papaya sample

were exposed during the optical tests, as shown on figure 01. Samples were then submitted to laser illumination by means of a 632 nm and 10 mW red laser having the images captured by SC-HMX20C SAMSUNG digital camera and processed by the ImageJ software.

III. Results and Discussions

Fig. 2 and Fig. 3 exhibit, respectively the samples with and without bruise and the corresponding image as generated by the Generalized Difference technique method.

Fig. 2 Sample 1 of papaya fruit exhibiting mechanical damage

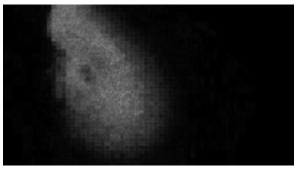

Fig. 3 Image generated by the Generalized Difference Method from sample **1**

Fig. 4 Sample 2 of papaya fruit exhibiting mechanical damage

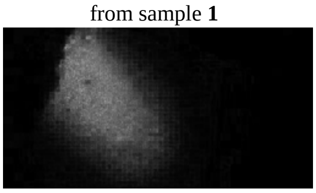

Fig. 5 Image generated by the Generalized Difference Method from sample **2**

Fig. 6 Sample 2 of papaya fruit exhibiting mechanical damage

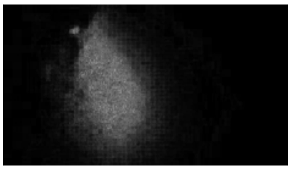

Fig. 7 Image generated by the Generalized Difference Method from sample 2

Fig. 8 Sample 2 of papaya fruit exhibiting mechanical damage

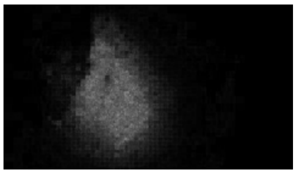

Fig. 9 Image generated by the Generalized Difference Method from sample 2

The above circles indicate the damage epicenter on the fruit surface as well as the areas of low bioactivity on the corresponding image where the observed dark spots indicate the damaged areas. It is evident that the damaged areas influence the bioactivity of the surface under consideration which can be mapped with the support of the Generalized Difference method.

Some areas on the fruit surface exhibit visual differences; however if they present similar bioactivity, it will be not feasible an optical differentiation by means of the method under consideration. Based on that consideration, it can be affirmed that the proposed technique is capable of differentiating occurrences on the tissue which are not visually detected by means of a conventional picture. Similar results are presented by Braga (2000) [6] which reported tests carried on bean seeds.

IV. Conclusion

Based on what it has been discussed above it can be concluded that the Generalized Difference Method is able of differentiating bruises generated on papaya flash.

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References

[1] Araújo Filho, Geraldo Correia de. [et. Al..] Produtor de Mamão – Fortaleza: Edições Demócrito Rocha; Instituto Centro de Ensino Tecnológico, 2002. 72p.

[2] FAO (Roma, Itália). FAO statistical databases: agricultural production: crops primary: Brazil: bananas. Disponível em: <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>. Acesso em: 08 jun. 2010.M.

[3] Arizaga, R.; Trivi, M. R.; Rabal, H. J. speckle time evolution characterization by co-ocurrence matrix analysis. Optics & Laser Technology, Oxford, v. 31, n. 2, p. 163-169, Mar. 1999.

[4] Bergkvist, A. Biospeckle-based study of the line profile of light scattered in strawberries. 1997. 60 p. Dissertação (Mestrado) - Faculty of technology at Lund University, Suécia.

[5] Braga Jr, R. A.; Rabelo, G. F.; Granato, L. R.; Santos, E. F.; Machado, J. C.; Arizaga, R.; Rabal, H. J.; Trivi, M. Detection of Fungi in Beans by the Laser Biospeckle Technique. Biosystems Engineering, San Diego, v. 91, n. 4, p. 465-469, Ago. 2005.

[6] Braga Jr., R. A. "Bio-Speckle" : uma contribuição para o desenvolvimento de uma tecnologia aplicada à análise de sementes. 2000. 117 p. Tese (Doutorado em Engenharia Agrícola) – Universidade Estadual de Campinas, Campinas.

[7] Xu, Z. J.; Joenathan, C.; Khorana, B. M. Temporal and spatial properties of the time-varying speckles of botanical specimens. Optical Engineering, Bellingham, v. 34, n. 5, p. 1487-1502, May 1995

[8] Enes, A. M. Análise do comportamento de tecidos vivos e tecidos mortos em sementes de feijão (Phaseolus Vulgaris L.) pela ótica do

biospeckle laser. 2005. 32 p. Trabalho de Conclusão de Curso (Graduação em Engenharia Agrícola) - Universidade Federal de Lavras, Lavras, MG.

[9] Enes, A. M.; Rabelo, G. F.; Braga Júnior, R. A.; Rodrigues, S. Utilização do Laser aplicado na diferenciação de tecidos vivos de tecidos mortos em sementes. In: Congresso Brasileiro De Engenharia Agrícola, 33., 2004, São Pedro. Anais... Campinas: Unicamp/Embrapa, 2004.

[10] Enes, Adilson Machado. Análise de resposta em freqüência do biospeckle laser. 2006. 48 p. Dissertação (Mestrado em Engenharia Agrícola) – Universidade Federal de Lavras, Lavras, MG.

[11] Moreira, M. F. B.; Braga Júnior, R. A.; Borem, F. M.; Rabal, H. J.; Rabelo, G. F.; Fabbro, I. M. Dal; Trivi, M. R.; Arizaga, R. Caracterização da Transmissão da Luz Laser em semente de feijão (Phaseolus vulgaris L.) . Revista Brasileira de Produtos Agroindustriais, Campina Grande, v. 4, n. 2, p. 119-126, 2002.

[12] Oulamara, A.; Tribillon, G.; Duvernoy, J. Biological activity measurement on botanical specimen surface using temporal decorrelation effect of laser speckle, Journal of Modern Optics, London, v. 36, n. 2, p. 165-179, Feb. 1989.

[13] Rabal, H. J.; Braga Jr., R. A.; Trivi, M. R.; Dal Fabbro, I. M. O Uso do Laser na Agricultura. In: Congresso Brasileiro De Engenharia Agrícola, 27., 1998, Poços de Caldas. Anais... Poços de Caldas: Sociedade Brasileira de Engenharia, 1998. 1CD-ROM.

[14] Rabelo, G. F. Avaliação da Aplicação do speckle Dinâmico no Monitoramento da Qualidade da Laranja. 2000. 149 p. Tese (Doutorado em Engenharia Agrícola) - Universidade Estadual de Campinas, Campinas.

[15] Rabelo, G. F.; Braga Junior, R. A.; Fabbro, I. M. D. . Laser speckle techniques in quality evaluation of orange fruits. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, v. 9, n. 4, 2005. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662005000400021&lng=en&nrm=iso>. Acesso em: 25 Set. 2006.

[16] Rodrigues, S.; Braga Junior, R. A.; Rabelo, G. F.; Enes, A. M.; Batista, C. A. M.; Dal Fabbro, I. M.; Resende, O. Efeito da umidade na determinação da atividade biológica de sementes de feijão. (Phaseolus vulgaris L.), utilizando imagens de speckle dinâmico. Revista Brasileira de Armazenamento, Viçosa - MG, v. 30, n. 2, p. 135-139, 2005.

[17] Romero, G. G. Estudio y caracterizacion de patrones de speckle que varian en el tiempo. 1999. 133 p. Tese (Doutorado em Física) - Universidad Nacional de Salta, Argentina.