

# Indirect determination of moisture using biospeckle technique<sup>1</sup>

Determinação indireta do teor de umidade utilizando a técnica de *biospeckle*

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**ABSTRACT** - The classification and selection of agricultural products are very important to assure post-harvest quality processes. However, most of physical and chemical analyses are destructive. It means those products turn useless after these analyses. Moisture is one of the most important parameters to assure the storage quality and as well to facilitate product processing. This research offers an alternative method to determine that parameter through an indirect and non-destructive way, using the image analysis based on the *Biospeckle* phenomenon. This method consists in get a 10 seconds video of a laser focused on the object. This video is divided in frames, using a computational routine in *Matlab* and, then, the sequence of images is processed using the computational program named *ImageJ*. The results are expressed in terms of modified correlation matrix and Moment of Inertia (MI). At the same time, a moisture analysis is carried out using the traditional methodology employing conventional heater equipment set at 130 °C. By correlating MI and moisture values, it was possible to determine the moisture content by means of an indirect method. To this research, it was employed grains of *Moringa oleifera*.

**Key words:** *Biospeckle*. Laser. Moisture. *Moringa oleifera*.

**RESUMO** - A classificação e a seleção de produtos agrícolas são de grande importância para garantir a qualidade dos processos de pós-colheita. No entanto, a maioria das análises físicas e químicas são destrutivas e isso significa que os produtos são inutilizados após essas análises. Sendo a umidade um dos mais importantes parâmetros para garantir a qualidade de armazenamento, bem como facilitar o processamento do produto, esse trabalho propõe um método alternativo para determinar esse parâmetro através de forma indireta e não-destrutiva, utilizando a análise de imagens a partir do fenômeno *Biospeckle*. Esse método consiste em obter um vídeo de 10s no qual o objeto é incidido por um laser. Esse vídeo é dividido em frames, utilizando rotina computacional no *Matlab* e, então, a sequência de imagens é processada, utilizando-se o programa computacional, *ImageJ*. Os resultados foram expressos em termos da matriz de correlação modificada e Momento de Inércia (MI). Em paralelo à análise de imagens, foi feita a análise de umidade através do método tradicional, empregando uma estufa a 130 °C. Correlacionando MI e os valores de umidade, foi possível determinar a umidade pelo método indireto. Para esse trabalho foram empregados grãos de *Moringa oleifera*.

**Palavras-chave:** *Biospeckle*. Laser. Umidade. *Moringa oleifera*.

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## INTRODUCTION

In order to guarantee fruits and vegetables quality to market, it's necessary to develop more accurate selection and sorting techniques. For this reason, an important research line explores nondestructive techniques.

The pertinent literature discloses several methods associated to quality determination that includes moisture content determination, seed viability, X-rays methods among others. *Biospeckle* techniques, which give tissue vitality level, are based on interference phenomenon that carries the information of the material. Guedes *et al.* (2014) evaluated kefir grains viability during the beverage production. Other authors aimed assess the shelf time of other products: Amaral *et al.* (2013) observed in beef color and the WBSF parameter during 21 days, Arefi *et al.* (2013) used biospeckle to compare fresh, semi-mealy and mealy apple and Alves, Braga and Vilas Boas (2013) identified respiration rate and water activity change in fresh-cut carrots.

This vitality is closely associated to tissue water content and is related to metabolic process intensity, which, in turn, influences the temporal variation of the interference *Biospeckle* (RODRIGUES *et al.*, 2005).

The optical interference phenomena can be noted when non-biological phenomenon or a diffusing object are lighting with the laser, and it's called dynamic *speckle* (RABELO, 2000).

In this research, the *Biospeckle* technique was evaluated using the Moment of Inertia (MI). It is based on *speckle* temporal variation. To quantify this variation, it was used the STS (*Time History Speckle Pattern*).

To distinguish the different levels of activity from the STS images, it becomes necessary to transform this image into a number or a quantification index (RABELO, 2000). Some calculations are necessary to this. Those related the probability of pixel intensity occurrence in each position of STS, resulting in a modified occurrence matrix (MOM).

According to Rabelo (2000), the occurrence values show how many times the intensity *i* is followed by the intensity *j* at the STS in the time sequence. If this intensity didn't change over time, just the main diagonal will have non-null values of occurrence matrix, what characterize the material as a low activity material. On the other hand, we have a high activity material when the intensity changes along the time and, then, some non-null values begin to appear out of the main diagonal.

It can be applied the concept of Moment of Inertia of second order to reach a numeric value to quantify the differences between two distinct images. This calculation

is applied on the MOM concerning its main diagonal in direction of lines, constituting the intensity dispersion module (MDI), also called in literature as MI (RABELO, 2000).

Based on that information, the present research was aimed to develop an alternative and indirect method to classify biological products based on its moisture, without destruct it.

It was used some grains of *Moringa oleifera* to develop that alternative method. It was used grains and not seeds, because in that case the objective was analyze just the influence of the water in the material.

The selection of *Moringa oleifera* is closed associated to its importance to many fields of knowledge. Particularly in water treatment, those grains can be used as an alternative to replace or to work together with the synthetic aluminum coagulant. But it's important to have low level of moisture.

## MATERIAL AND METHODS

It was used *Moringa oleifera* grains for this research work. The grains were dried in the oven for 2 hours in 130 °C to ensure that all the grains were kept dry (the initial average moisture was 7%), as it was described at MAPA (BRASIL, 2009).

After this, the process of grain humidification was carried, using a 0.5% of salt solution (NaCl). Some shelled grains were allocated in a container and then it was added the salt solution, as is showing in Figure 1.

The grains were weighed to calculate the moisture in some time intervals as: 0h, 0.25 h, 0.5 h, 0.75 h, 1 h, 1.5 h, 2 h, 2.5 h, 3 h, 4 h, 5 h, 6 h, 7 h, 21 h, 23 h and 27 h. At these times, it was made the 10 seconds videos to the *Biospeckle* image.

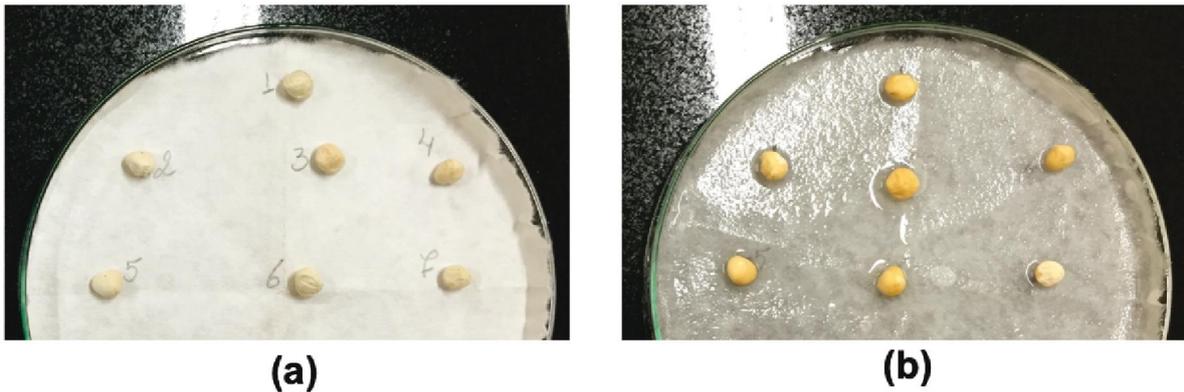
The moistures were determinate by using the Equation 1, where:  $m_{ai}$  is the weight of water in the initial time;  $m_0$  is the inical weight (dry grains +  $m_{ai}$ ); and  $m_a$  is the weight of water absorbed by the grain.

$$\%U = m_a / (m_0 - m_{ai}) \cdot 100\% \quad (1)$$

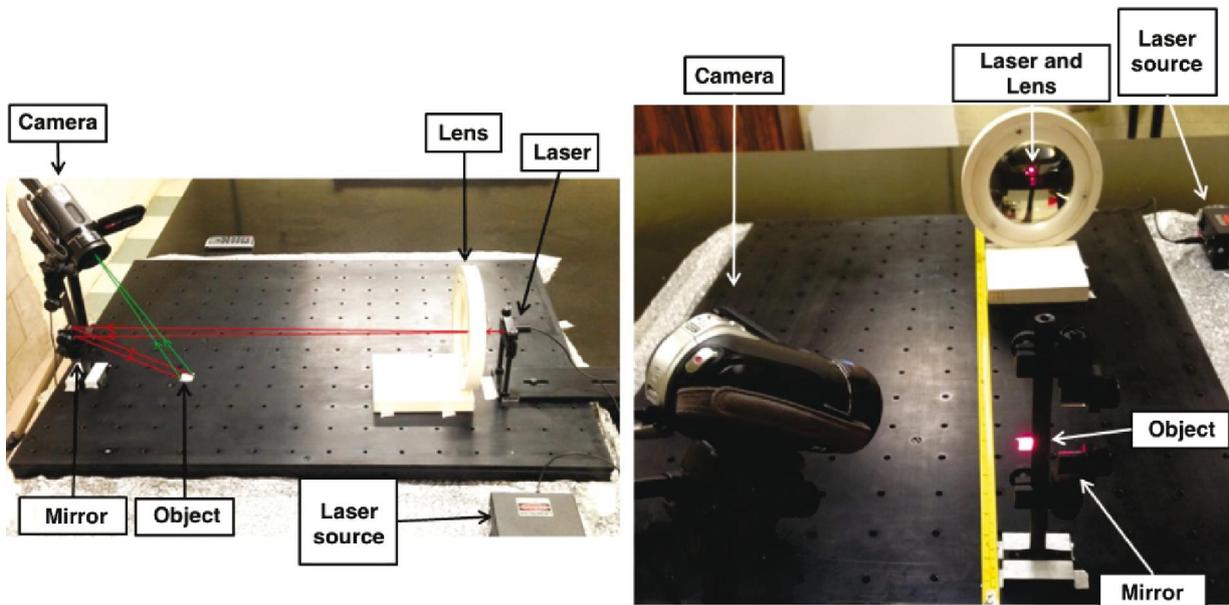
To analysis of *Biospeckle*, it was used the method named "Moment of Inertia" (MI). The sample was indirectly lighted with a red diode laser (632 nm), which had 10 mW of power. The experimental setup is showing in Figure 2.

By using a CDC camera (Samsung Digital Cam CM OS 6.4 Mega Pixel Full HD), it was made a video during about 10 seconds. From that video, it was

**Figure 1** - The *Moringa oleifera* grains before (a) and after (b) the humidification



**Figure 2** - Experimental Setup



obtained an image sequence of 512 images, using some computational routines applied in these computational programs: *Matlab* and *ImageJ* (this last one can be free downloaded in <http://rsbweb.nih.gov/ij/>).

After this, it was used more two computational routines in *ImageJ* to obtain a value of the parameter called Moment of Inertia (MI), the Modified Correlation Matrix (MOM) and the STS standard (*Spatial Temporal Speckle*).

With that information about moisture and MI, it was made the correlation of the two parameters to be able to do the indirect determination of moisture using the MI. It was drawn an exponential trend line.

## RESULTS AND DISCUSSION

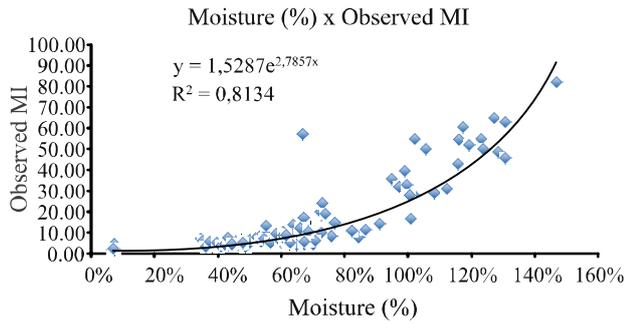
All the obtained points were used to plot the chart showed in Figure 3. Then, it was drawn an exponential trend line.

It's possible to see that when there was the increase of the moisture, the observed MI increase too. The behavior of this raise follows the  $y = 1,5287e^{2,7857x}$  Equation 2:

$$y = 1,5287e^{2,7857x} \quad (2)$$

The reliability of this correlation is 81,34%.

**Figure 3** - Relation between the moisture (%) and the observed MI to each point



Enes *et al.* (2005) also verified the percentage of moisture and the MI result. The difference with this study is that they didn't show explicitly the correlation between moisture and MI; they observed the behavior of each parameter along the time. But they observed that along the time both parameters presented reduction.

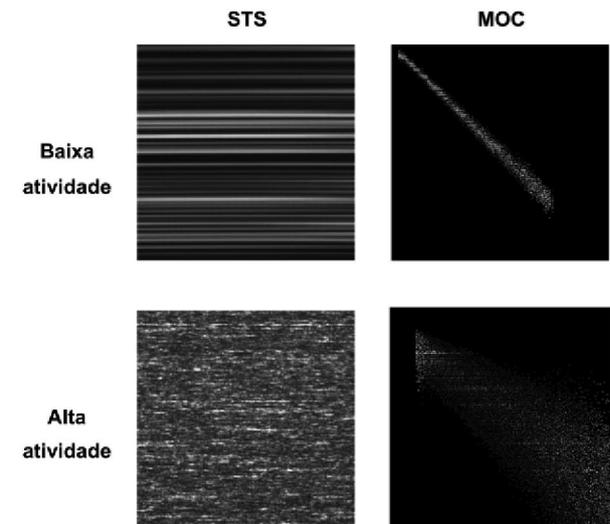
To obtain those values, it was generated some image sequence. Based on that image sequence, it was taken some steps using some computational routines, which resulted in one STS standard (*Spatial Temporal Speckle*) and one Modified Correlation Matrix (MOM) to each time of the water absorption analysis. Those two image results are showed at Figure 4 and Figure 6, respectively.

At Figure 4 it's possible to observe a significant difference between the STS standard at the first time and the others. In the beginning of the analysis, it's possible to see some almost straight lines, which represent a low activity material. In that case, this activity represents just the water activity because the grains were previously dried using a high temperature. That image looks like the STS standard to low activity materials, as Rabelo (2000) shown at his research (Figure 5).

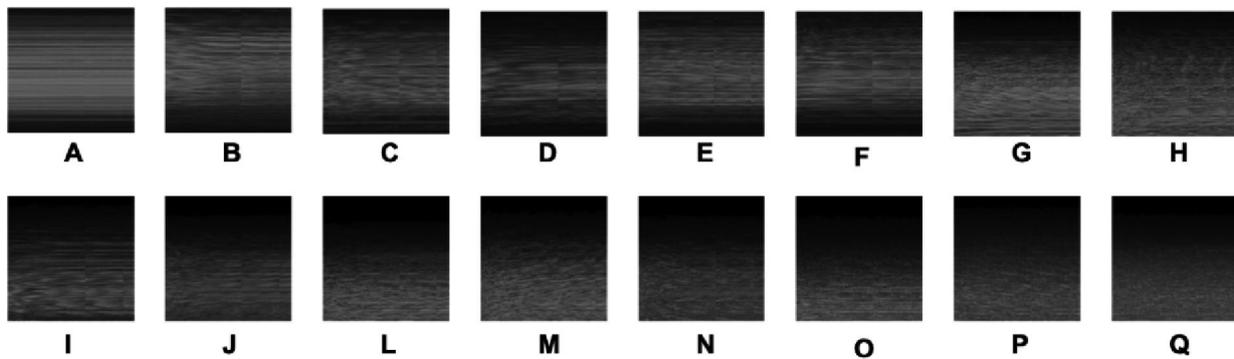
Differently of this first image, while the grain was absorbing water, the MI value was growing and those almost straight lines look like interference on television. It represents a high activity material, as Rabelo (2000) showed at (Figure 5).

Analogously to STS Standard, it's possible to observe that during the water absorption there are the increases of MI values and the variation of the Modified Correlation Matrix. Rabelo (2000) said that during the increase of MI values, there are more non-nulls values at main diagonal. This behavior can be observed at the image sequence showed at Figure 6: at time 0h it's possible to see a diagonal without points out of the main diagonal. Along the process, a kind of cloud of points beginning to appear and the main diagonal beginning to be less defined. That's the same behavior that could be seen at the example at Figure 4.

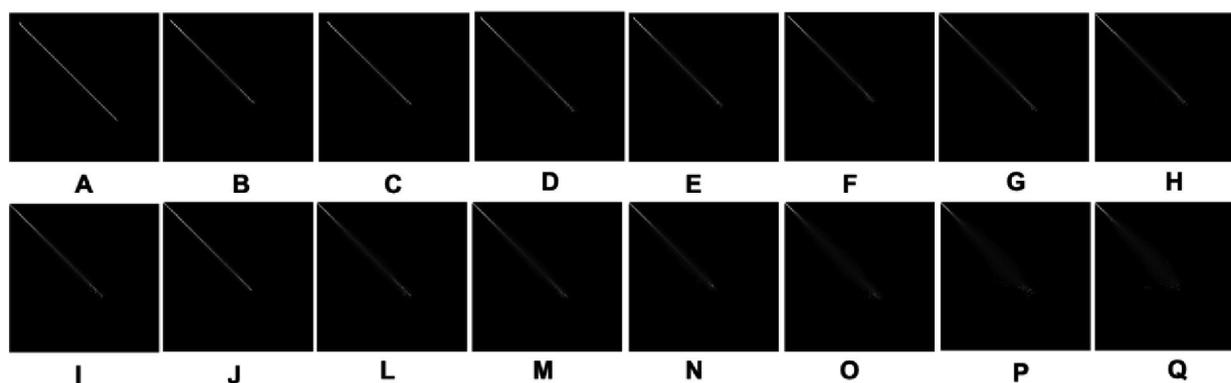
**Figure 5** - STS e MOM of low and high activity materials (Adapted by RABELO, 2000)



**Figure 4** - Variation of STS Standard during the 27 h of water absorption, from A to Q, respectively, 0 h; 0,25 h; 0,50 h; 0,75 h; 1,0 h; 1,5 h; 2,0 h; 2,5 h; 3,0 h; 4,0 h; 5,0 h; 6,0 h; 7,0 h; 21,0 h; 23,0 h; and 27,0 h



**Figure 6** - Variation of Modified Correlation Matrix during the 27 h of water absorption, from A to Q, respectively, 0 h; 0,25 h; 0,50 h; 0,75 h; 1,0 h; 1,5 h; 2,0 h; 2,5 h; 3,0 h; 4,0 h; 5,0 h; 6,0 h; 7,0 h; 21,0 h; 23,0 h; and 27,0 h



## CONCLUSION

It was found the correlation between the moisture and the Moment of Inertia value of the grains: the activity grows with the water absorption.

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