

Estimation of Moisture Content in Edible Pulses by the Application of Computerized Tomography

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Abstract

Moisture content is an important component in food products. Proper information about the moisture quantity in the grains is a valuable parameter to evaluate the quality and stability of the food products. Now a days Tomographic image processing plays an important role to monitor and ensure the quality of food products [1]. Present work focuses on use of Computerized tomography for the estimation of moisture content in pulses. Three different types of pulses (Arhar, Masoor, and Urad) are scanned by a micro X-ray CT scanner installed at IIT Kanpur. These experiments are carried out with 800 projection views and 120 kV applied voltage to X-ray source. The 2-d detector system consists of photodiodes which generate 1024 data rays [2-3]. Avizo software which uses FDK (Feldkamp-Davis-Kress) algorithm has been used here to reconstruct the CT images [4-5].

Introduction

Nondestructive Testing (NDT) using computerized tomography is a very popular inspection method for variety of engineering aspects. Modern high resolution CT scanners with advanced technology can scan cross section with pixel size up to nano meters. Computed tomography (CT) is one of the emerging technologies of interest to the food industry also as it allows a non-destructive characterization and control of food products throughout the elaboration process. Analyzing the tomographic image we can gather lots of information about the object we have scanned. Here three different types of pulses (Arhar, Masoor, Urad) have been scanned. Each pulse is scanned dry, with 5% water, 10% water and 15% water. Tomographic images are reconstructed using FDK (Feldkamp-Davis-Kress) algorithm and then the concept of Fractal Dimension (FD) has been used to analyze the quality of reconstructed image [6]. Fractal theory is widely used in the study of image texture and analysis of the material surface. FD varies with the changing amount of moisture content in the pulses and the moisture content is estimated from the change in FD.

FDK Algorithm

Feldkamp, Davis, and Kress (1984) described an approximate reconstruction method for circular cone-beam tomography which is known as FDK algorithm. Mainly the algorithm is a type of

analytical reconstruction methods. The algorithm involves weighting, filtering and back-projection of data for each projection over the 3D reconstruction volume. There will be certain amount deviation in the reconstructed image from the measured object regardless of the measurement resolution. For moderate cone-angles, these differences are however small and often acceptable. The simplicity of the FDK method has made it the most used algorithm for cone-beam reconstruction. An important advantage of the FDK method is that it works well with truncated projections since the filtering is only performed in the un-truncated fan-direction. Feldkamp et al. (1984) observed the following property of the FDK method

- The FDK is fast and robust but requires a rather dense number of projections taken around 360°. When only a limited number of projections are available, the FDK as a filtered back-projection based method is affected by artifacts. This is due to the fact that all three-dimensional Radon data at $z = 0$, i.e. all plane integrals of the planes perpendicular to the mid-plane, can be computed from the projections obtained with the single circular scan.

Fractal Dimension

Fractals are infinitely complex patterns that are self-similar across different scales and Fractal Dimension (FD) is a ratio providing a statistical index of complexity comparing how detail in a fractal pattern changes with the scale at which it is measured. Thus FD represents a reasonable quality index for the reconstructed image [7-8]. Very popular Box-Count method is used here for FD measurement [9]. In this section, the algorithm for estimation of the fractal dimension of a 2-D digitized image is discussed. Here $I(x, y)$ represents the intensity value of any such pixel with Coordinate x, y , where $x, y=0, 1, 2 \dots M-1$. The fractal graph of any such image is visualized as the plot of Log (NMSID) vs. Log (NSR) . The following parameters are defined below:

1. **Scale:** It is the Δr distance between two pixels.
2. **NSR:** The NSR corresponds to the normalized scale range vector and it consists of reference scale and generally corresponds to the possible distances between any pair of pixel in the concerned image. Thus

$$\text{NSR} = [\text{ndr}(1), \text{ndr}(2), \dots, \text{ndr}(k), \dots, \text{ndr}(m)] \quad (1)$$

Where k is an integer $\text{dr}(k) = k$ and the n value depends on practical considerations.

In general for an $M \times M$ image, we can select n to be M , then $\text{NSR} = [1, 2, 3, \dots, M]$.

3. **NPN:** Normalized Pixel Pair Number vector. The normalized pixel pair number NPN vector consists of elements which are the number of pixel pairs with distance values whose integer parts are the same integer reference scale. Formally

$$\text{NPN} = [\text{npn}(1), \text{npn}(2), \text{npn}(k), \dots, \text{npn}(n)] \quad (2)$$

Where $n_{pn}(k)$ is the total pixel pairs with distance Δr and $k < \Delta r < k + 1$.

4. **NMSID:** Normalized Multi-Scale Intensity Difference vector. It consists of different absolute-intensity difference averages around each normalized reference scale (NSR), i.e.,

$$\text{NMSID}=[\text{ndi}(1),\text{ndi}(2),\dots,\text{ndi}(k),\dots,\text{ndi}(m)] \quad (3)$$

Where $\text{ndi}(k)$ is the average of absolute intensity difference of all pixel pairs with Distance values whose integer parts are $\text{ndr}(k)$.

$\text{Log}(\text{NMSID})$ vs. $\text{Log}(\text{NSR})$ for $I=1,2, \dots, M$, plot results in a curve consisting of M points which is the fractal graph of the corresponding image. A linear fractal graph represents a perfect fractal, otherwise a least square linear regression on it gives the slope (H) of the resultant curve. The fractal dimension FD is then calculated from the relation

$$FD=3-H \quad (4)$$

Any digitized image with different intensity values on its pixels is conceived as an imperfect cube in which the fractal dimension should lie in between 2 and 3. Moreover, it is important to note that the FD , evaluated as above, will vary since the slope of the best linear fit depends on the range-of-scales of distances being selected. It is a common practice to consider the range of NSR in which the fractal graph exhibits linear behavior. Real surfaces and images cannot be true mathematical fractal as they do not exhibit fractal behavior over all ranges of scales. So when we determine fractal dimension for an image we have to consider certain range of scales. Upper limit of this range is set by the overall size of the image and lower limit is set by pixel size. H is obtained by considering a normalized scale range over which the slope of normalized scale range over which the slope of plot is linear. Specifically written matlab code gives the $\text{Log}(\text{NMISD})$ vs $\text{Log}(\text{NSR})$ and thus the Hurst coefficient (H) and Fractal Dimension (FD). FD varies with the changing amount of moisture content in the pulses and the moisture content is estimated from the change in FD .

Experimental Details

Three different types of pulses (Arhar, Urad and Masoor) have been scanned with the help of X-ray CT Mini scanner, installed at Divyadrishti Prayogshala, IIT Kanpur. A set of experiments consisting four different moisture contents (dry, 5%.10%, 15% water content) is performed with each pulse. This setup (Procon X-ray GmbH) provides 3D data for cone beam geometry. Focal spot of X-ray tube is 7 micron and a flat panel detector of 1024x1024 photo-diodes is used to detect attenuated X-ray radiations. Source-detector system is fixed and the object can rotate for full 360 degrees. The intensity of X-ray radiation was measured with 16-bit data resolution. Detector system makes a cone beam angle of ± 7.90 on the X-ray source. Following initial parameters shown in Table 1 are set in X-ray machine set up to perform experiment with each sample.

Sl. No.	Parameter	Values
1	Voltage	120kV
2	Current	120 μ A
3	Resolution	65.1 μ m
4	Exposure Time	250ms
5	Source to Object Distance	29.5cm
6	Projections	800
7	End Time	30mins

Table 1: CT scanner parameters for the Experiments

Software named Avizo (Fire edition) is used for 3D data visualization. It is used in Material Science, Non Destructive Testing and industrial inspection. It is packaged in different editions for simulation of different types of applications.

Experimental Results

Reconstructed images from the projection data for the pulses are shown here. Figure 1 shows the reconstructed images (only middle slices) of the scanned Arhar Pulse.

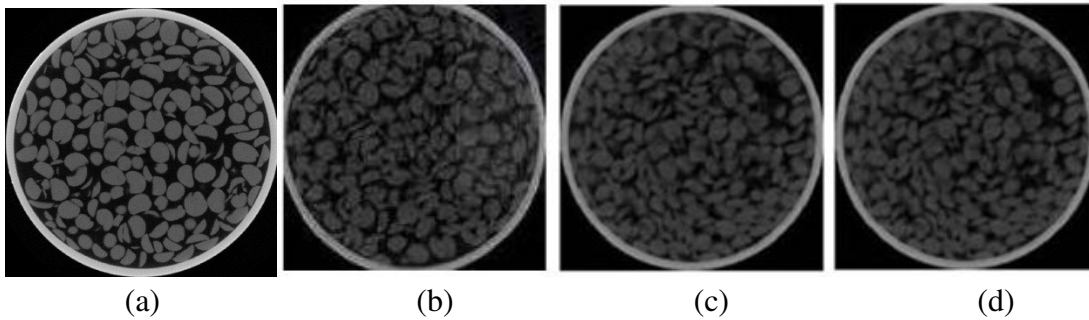


Figure 1: Middle slices of each sample (a) dry, (b) with 5% water, (c) with 10% water, (d) with 15% water

Same way we have scanned the other two pulses (Masoor and Urad) also. Specifically written Matlab code gives the fractal graphs (Log (NSR) vs. log (NMSID)) as output for each of these reconstructed images. Figure 2 shows fractal graph for corresponding gray scale middle slice images.

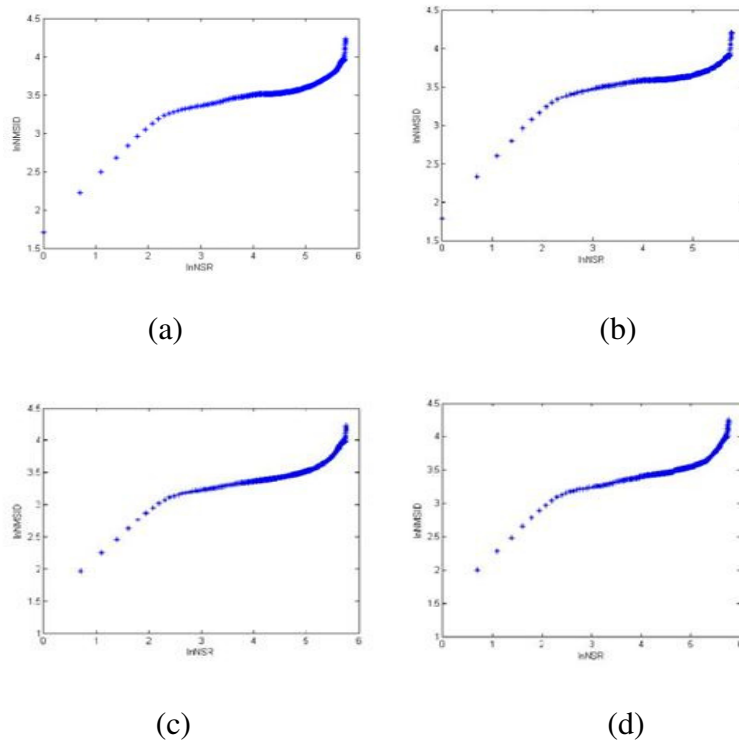


Figure 2: LogNSR vs. LogNMSID plot for Arhar Pulse (a) when dry, (b) with 5% water, (c) with 10% water, (d) with 15% water content

We have discussed earlier that the slope of LogNSR vs. LogNMSID plot is the Hurst Coefficient(H) and Fractal Dimension(FD) can be calculated from the relation $FD=H-3$. When the pulses are dry then H for Arhar pulse is 0.088314 and $FD = 2.911482$. For the dry Masoor and dry Urad pulse FD values are 2.902628 and 2.904378 respectively.

Calculated FD values for 5% , 10% and 15% moisture content for Arhar pulse are 2.89361, 2.880727, 2.870837 respectively (measured between lower limit of pixel size 1mm and upper limit of pixel size 8.75mm) . Same way we have the values for Masoor and Urad pulses also.

A change has been observed in Fractal Dimension of pulses because increasing of moisture content. The change in FD for different pulses is indicated in the Table 2.

Pulse	FD without water	FD with 5% water	%Change in FD(5% W)	FD with 10% water	%Change in FD(10% W)	FD with 15% water	%Change in FD(15% W)
Arhar	2.911482	2.89361	0.61369	2.880727	1.05633	2.870837	1.3960
Masoor	2.902628	2.88924	0.4611	2.87384	0.99177	2.879745	0.78833
Urad	2.904378	2.89236	0.41355	2.88974	0.50373	2.885009	0.66688

Table 2: Changes in FD for 5%, 10% and 15% added water

Conclusion

The results show that change in FD is varying with moisture content. For different pulses, the change in FD is different. Water content is estimated by finding the change in FD. As the surface gets smoother, the value of FD increases. For fresh pulses, the value of FD is greater than the pulses having some water content. Increased water content worsens the surface as well as lowers the value of FD. Thus FD is proved to be a generalized texture quality index of food material. It can be a valuable parameter for food industries to ensure the quality index and can be helpful in the assessment of shipping & storage conditions of food material.

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