Monitoring Quality Control of Fruits Using Terahertz Sensing

Citation for published version:
Ren, A, Zahid, A, Imran, MA, Abbasi, QH & Alomainay, A 2019, Monitoring Quality Control of Fruits Using Terahertz Sensing. in *2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting.* IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, IEEE, pp. 381-382, 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Atlanta, United States, 7/07/19. https://doi.org/10.1109/APUSNCURSINRSM.2019.8888479

Digital Object Identifier (DOI):
10.1109/APUSNCURSINRSM.2019.8888479

Published In:
2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting

Establishing a Novel Method for Monitoring Quality Control of Fruits Using Terahertz Sensing

Aifeng Ren[a,b]
[a]School of Electronic Engineering
Xidian University, Xi'an, Shaanxi, China
afren@mail.xidian.edu.cn

Adnan Zahid[b], Muhammad Ali Imran[b], Qammer H. Abbasi[b]
[b]School of Engineering
University of Glasgow, Glasgow, UK
a.zahid.1@research.gla.ac.uk,
{Muhammad.Imran, Qammer.Abbasi}@glasgow.ac.uk

Akram Alomainy[c]
[c]School of Electronic Engineering and Computer Science
Queen Mary University of London, London, UK
a.alomainy@qmul.ac.uk

***Abstract*—This paper presents a novel application of terahertz (THz) sensing to monitor the quality of fruits by detecting the moisture content (MC) and the transmission response. The preliminary results show that the difference of loss in MC value from day 1 to day 3 is only 15% for pear slice, while that is 62% for apple slice, which causes the significant difference in the transmission response between pear and apple slices in the first 3 days. The results indicate that the relationship between the concentration of inner substances and the path loss of the THz radiation is very close to the absorption characteristics of the samples in the THz region. The application presented here can be extended to analyze the internal dielectric properties of fruits and obtain the spectral signatures of different compositions and the biomass quality control in fruits.**

I. Introduction

The terahertz (THz) radiation corresponds to the frequency range of 0.3 THz to 3 THz. It has been demonstrated that the particular frequency range is a feasible and efficient solution in the detection of water content, which was on the basis of the absorption of THz waves in molecular and bio-molecular systems due to the better sensitivity of THz radiation to moisture content (MC) [1]. Compared with the other existing methods based on near-infrared and mid-infrared radiation technologies, the THz technology can detect more detailed information about the inner intermolecular characteristics and physiological state of biological materials in the THz region [2]. There exist strong correlation property between the concentrations of pesticide in fruits and vegetables which depended on the MC and the THz spectra [3]. Therefore, keeping in view of the correlation, the THz technology is considered to be the ideal solution for the quality control of fruits, in order to identify the microbial and heavy metal contamination during the preservation and processing.

Moreover, the detection of the internal factors of the fruits including the nutrition, substances and microbial contaminants have become increasing important for preserving and processing due to the change in water content and the concentration of the complex composition with the storage days. The bio-impedance measurement being independent of uncontrollable factors has been explored as a feasible and non-destructive method for the determination of internal quality control and microbial contamination [4]. Subsequently, the techniques for assessing the quality parameters of the fresh fruit and vegetable from both external and internal aspects were studied as in [5]. The authors stated that the MC and the physiological information are significant for characterizing the internal quality. In [6], the results indicate that the detection of dielectric properties affected by the MC is highly valuable to understand the behaviours of food materials when exposed to radio frequency (RF) radiation to determine the quality.

This paper presents a novel, non-invasive and easily-applicable method to monitor the variations of the MC in different kinds of fruits such as pear and apple (slices) when exposed to the THz radiation. The primary aim of this work is to analyse the transmission response of samples obtained from measurements using vector network analyzer (VNA) connected the Swissto12 system sweeping the frequency from 0.75 THz to 1.1 THz. The measurements results obtained show that the differences of transmission response and path loss are clearly distinct related to the MC in the fruit slices. These preliminary observations provided adequate information to explore the internal characteristics through the dielectric properties of fruits from the regulations of electromagnetic parameters in the THz region.

II. Materials and Methods

The Material Characterization Kit (MCK) Swissto12 system was set up and calibrated with two-port Short-Open-Load-Thru (SOLT) criterion to minimize the errors and losses caused by the measurement system [7]. Subsequently, the pear and apple slices taken as samples with the thickness range from 40μm to 4mm were put exposed to examine the reflection (S11, S22) and transmission (S12, S21) parameters, respectively. All the sample slices were analysed carefully under the ambient temperature of 18°C ± 0.2°C and humidity of 30% ±2%. Moreover, the measurements for each slice were taken at four points, and each point was exposed at four angles to collect data with three readings each time. The transmission measurements of samples were obtained three times every day with two hours different for nine consecutive days using Swissto12 system, as shown in Fig. 1. The weight for each slice was obtained before taking measurement using digital scale with count of 0.1mg. The weight was converted into moisture content value, MCvalue, as in (1) to calculate the variation of MC with the passage of time [8].

$$\text{MC} = \frac{W_{time} - W_{dry}}{W_{time}} \times 100\% \tag{1}$$

where W_{time}, indicates the weight of the sample at particular time interval. W_{dry} is the weight of the sample dried out completely. The variation rate and range of MC of pear and apple samples were shown in Fig. 2.

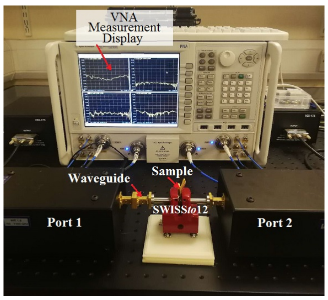

Fig. 1. Equipment setup with Swissto12 THz system.

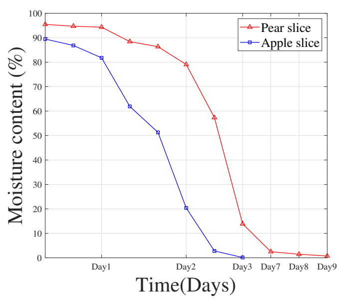

Fig. 2. Moisture contents of samples with days.

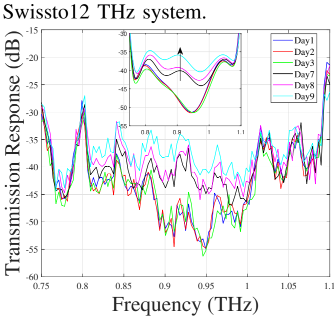

Fig. 3. Transmission response of pear slice.

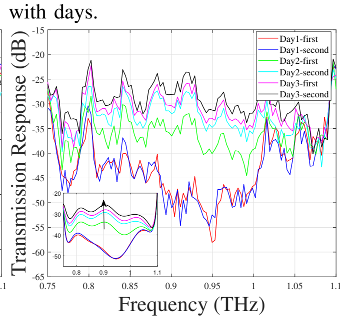

Fig. 4. Transmission response of apple slice.

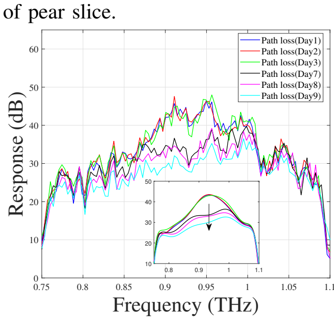

Fig. 5. Path loss of pear slice.

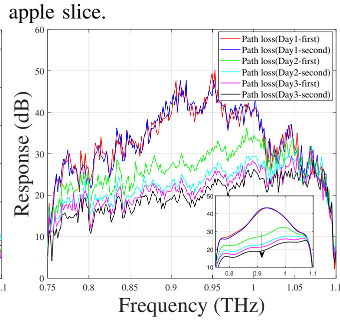

Fig. 6. Path loss of apple slice.

III. Results and Discussion

The MC patterns of different slices were shown in Fig. 2. This indicates the decaying patterns of the freshness of the pear and apple slices which were exposed to air as the days progressed. The transmission response of pear and apple slices, shown in Fig. 3 and Fig. 4, illustrate the THz characteristics of two fruits in the same THz region. A distinct variation can be observed in transmission response of pear slice on day 3 to day 9 as shown in the embedded fitting curves, however, the difference was not very noticeable on day 1 to day 3 due to high MC value. Compared to the pear slices, the significant difference was observed on day 1 to day 3 for apple slice as shown in Fig. 4, even on the same day between two times measurements. Observed the trend of MC as shown in Fig. 2, the difference of the water loss from day 1 to day 3 was 60.88% for the pear slice and 49.79% for the apple slice. Nevertheless, the difference of the MC value was very significant, which was 15.26

In addition, the path loss of samples obtained over the course of passing days was shown in Fig. 5 and Fig. 6, respectively. From the embedded fitting curves, the samples showed a clear difference between transmission and absorption with the variation of MC, as shown in Fig. 2, in the THz frequency range from 0.85 THz to .1.0 THz. Meanwhile, observed the surface of the pear and apple slices, the appearance of pear slice was more sticky than that of apple slice with the passing days, which indicated that the different internal characterization of fruits related to the MC.

IV. Conclusion

This paper highlighted the comparison of THz characterization of fruits by applying the transmission response and path loss obtained by employing VNA-based techniques with Swissto 12 system in the frequency range between 0.75 THz to 1.1 THz. The moisture contents of samples obtained over the passage of time were derived as the reference for determining the difference between transmission and path loss response. The results indicated that the different substances in the fruits will merge the difference THz characteristics in the THz region due to the loss of the moisture, which is one of the important factors to detect the quality of the fruits. The proposed method in this paper can be extended to analyse and control the quality of fruits and vegetables in terms of identifying the moisture content.

References

[1] S. K. Mathanker, P. R. Weckler, and N. Wang, “Terahertz (THz) Applications in Food and Agriculture: a Review,” *Transactions of the ASABE (American Society of Agricultural and Biological Engineers)*, Vol. 56(1), pp.1213—1226, April 2013.

[2] Á. Kertész, Z. Hlaváčová, E. Vozáry, and L. Staroňová, “Relationship between moisture content and Electrical impedance of carrot slices during drying,” *Int. Agrophysics*, Vol. 29(1), pp.61–66, Jan 2015.

[3] T. Suzuki, Y. Ogawa, and N. Kondo, “Characterization of pesticide residue, Cis-permethrin by terahertz spectroscopy,” *Eng. Agric. Environ. Food*, vol. 4(4), pp. 90-–94, 2011.

[4] U. Pliquett, ”Bioimpedance: A Review for Food Processing,” *Food Eng. Rev.*, Vol. 2, pp. 74–94, 2010.

[5] P. Butz, C. Hofmann, and B. Tauscher, “Recent Developments in Noninvasive Techniques for Fresh Fruit and Vegetable Internal Quality Analysis,” *J. Food Sci.*, 2006.

[6] K. Sacilik, C. Tarimci, and A. Colak, “Moisture content and bulk density dependence of dielectric properties of safflower seed in the radio frequency range,” *J. Food Eng.*, 2007.

[7] A. Zahid, K. Yang, H. Heidari, C. Li, M. A. Imran, A. Alomainy, Q. H. Abbasi, “Terahertz characterisation of living plant leaves for quality of life assessment applications,” in Baltic URSI Symposium, 2018.

[8] P. Nie, F. Qu, L. Lin, T. Dong, Y. He, Y. Shao, Y. Zhang, “Detection of water content in rapeseed leaves using terahertz spectroscopy,” Sensors, Vol. 17(12), 2830, 2017.