Introducing a Novel Technique of Detecting Fruits Contaminations Using Terahertz Sensing

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***Abstract*—This paper mainly presents preliminary results by employing terahertz technology for determining the moisture content (MC) of fruits slices over the course of seven days. In this paper, a novel technique has been presented to determine the transmission and path-loss response of fruits during the loss of moisture content by employing the integrated system of vector network analyzer (VNA) techniques and Swissto12 system over the frequency range from 0.75 THz to 1.1 THz. The results presented in this paper showed that the decreasing MC with the every passing day caused the differences in transmission and path-loss response, which further indicates that the different concentration of substances in fruit emerges a unique absorption characteristic. The application proposed here can be employed for the feasible and non-invasive method of determining the quality control of fruits.**

***Index Terms*—terahertz wave, fruits, transmission response, path loss, moisture content**

I. Introduction

Over the past decade, the terahertz (THz) radiation range from 0.3 THz to 3 THz has become the significant technology to recognize the microscopic properties of materials on the food quality and its safety inspection including biomedical imaging and microbiological contamination detection [1] [2]. In [3], the study showed that the difference of dielectric properties in fruits caused the differential radio frequency (RF) heating rates of water and fruit mixtures. Owing to the complex composition of each kind of fruit including water, protein, carbohydrate (mainly sugars), fibre and abundant vitamins, the knowledge about the characterization of fruits is crucial for preserving and processing the effective and quality method in controlling to apply an efficient method in order to process and preserve them properly.

In the past, many functional techniques such as nuclear magnetic resonance (NMR) [4], near-infrared (NIR) [5] and terahertz (THz) imaging [6] have been widely applied for analysis of the metabolites in various fruits and vegetables, such as determination of freshness and other composites levels in fruits such as proteins, sugar, and fats [7]. However, due to limited accessibility, low resolution and less sensitivity at molecular changes in fruits. These aforesaid approaches have been unable to obtain detailed information about internal morphology of fruits inviting health and purification expenses incurring nutrients and toxins increments [8]. In comparison, THz technology can be more cost effective, reliable and unique solution due to its high sensitivity and deep penetration feature and to detect any pesticides at a very early stage to avoid any unnecessary costs [2] [9]. In addition, due to the better sensitivity of THz radiation to moisture content (MC) of different samples, the potential of THz technology can provide more detailed intermolecular information to pave way for a more accurate and economical way of analysing the food compositions. Hence, the THz technology can be a good candidate to monitor and control the quality of fruits and vegetables [2] [10].

The paper is aimed to present a novel, non-invasive and simple approach of applying terahertz (THz) technology to study and monitor the variations of moisture content of the pear fruit slices by determining the transmission response of sample derived from measurements of vector network analyzer connected to the Swissto12 system with frequency ranging between 0.75 THz to 1.1 THz. The results showed that the differences of THz characterization of samples were very clear with the loss of moisture in the fruit slices. These preliminary observations lead to meaningful information to explore and analyse the presence of any pesticides in fruits within the THz region. It also lays the foundation to study the spectral signatures of different compositions and the biomass quality control of different processes in fruits.

This paper is organized as follows: Section II presents the method and overall experimental set-up for the measurement, Section III discuss the results including the analysis and

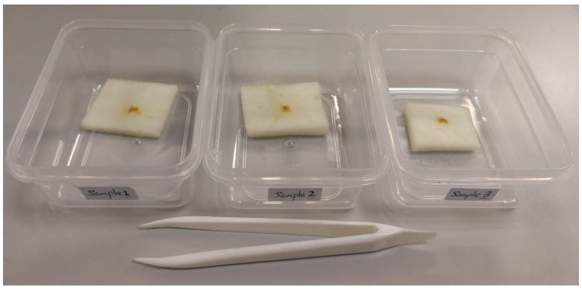


Fig. 1: Three Samples of Pear slices.

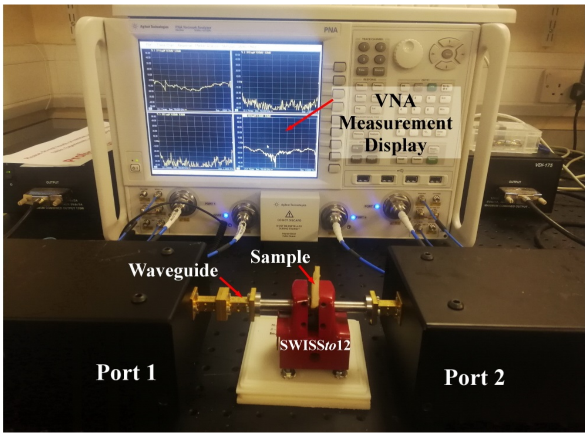


Fig. 2: Experimental equipment setup for measuring the transmission response using Swissto 12 THz system.

Finally, in section IV, the conclusion is presented.

II. Methods

In order to obtain measurements of fruit samples, it was important to set up the Material Characterization Kit (MCK) Swissto12 system. A fully two-port known as (Short-Open-Load-Thru) calibration was performed to the system to lessen the system's and measurement errors and transmission losses that may occur whilst performing measurements [11]. Hence, both reflection (S11, S22) and transmission (S12, S21) coefficients were determined for all three samples. In this case, three pear slices having a thickness in the range of (40µm-4mm) was taken as samples for measurements to be performed, as shown in Fig. 1. All the slices were examined under the tested environment temperature which was set to 17°C ± 0.1°C and humidity was between 30% ±2%. Four various locations on all slices were considered to determine the moisture content and freshness of fruit for consecutively seven days. Moreover, on every location, further four orientations were taken into consideration to investigate the behaviour of all slices more deeply about and to see any changes in moisture level of samples. The weight of all slices was also measured after every 2 hours for consecutive seven days using a digital scale with an at least count of 0.1mg. The transmission measurements of samples were obtained employing Swissto 12 system, as shown in Fig. 2.

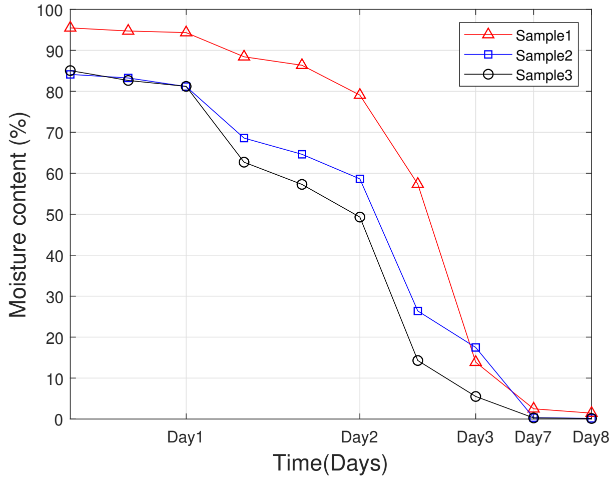


Fig. 3: Moisture content of three samples was determined from day 1 to 8.

TABLE I: Weight and Moisture Content of Samples

Time (Day)	Sample1		Sample2		Sample3	
	Mass(g)	*MC(%)*	*Mass(g)*	*MC(%)*	*Mass(g)*	*MC(%)*
1	6.030	95.47	7.558	84.12	4.815	85.05
	5.165	94.71	7.165	83.25	4.148	82.64
	4.809	94.32	6.368	81.15	3.829	81.20
2	2.358	88.42	3.819	68.58	1.930	62.69
	2.000	86.35	3.392	64.62	1.685	57.27
	1.304	79.06	2.900	58.62	1.420	49.30
3	0.640	57.34	1.630	26.38	0.840	14.29
	0.317	13.88	1.454	17.47	0.762	5.51
7	0.280	2.50	1.204	0.33	0.722	0.28
8	0.277	1.44	1.202	0.17	0.721	0.14
9	0.273	0	1.200	0	0.720	0
10	0.273	0	1.200	0	0.720	0

III. Results and Discussions

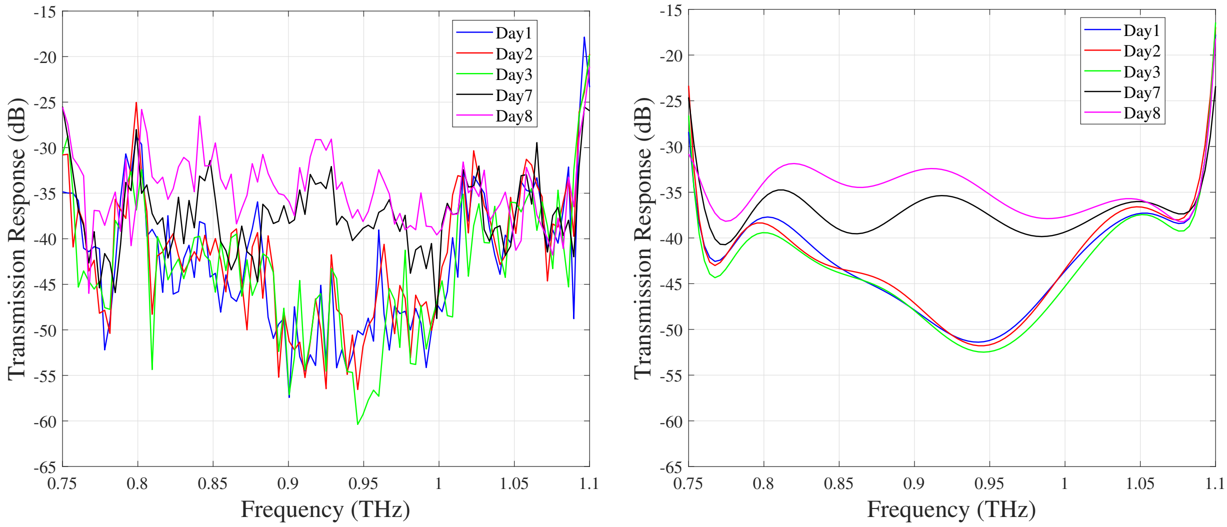
The moisture contents of three sample slices were obtained and are shown in Fig. 3. To obtain the variation of moisture content during the evaporation of water content in slices with every passing day, the weight of each slice was measured and converted into moisture content value by equation (1) [12].

$$\text{MC} = \frac{W_{day} - W_{dry}}{W_{day}} \times 100\% \qquad (1)$$

The denominator, W_{day}, was the weight of the sample taken before measurements were performed, W_{dry} was the weight of the sample after the sample completely dried out. It was noticed that there was clear loss obtained in the weight of samples due to the evaporation of moisture content with every passing day as shown in Table I. Table I represents the weight of each slice and corresponding moisture content numerically.

From Fig. 3, it was observed that all samples followed a similar pattern when exposed to air and evaporation of samples indicating the freshness of fruits dropping down with every passing day.

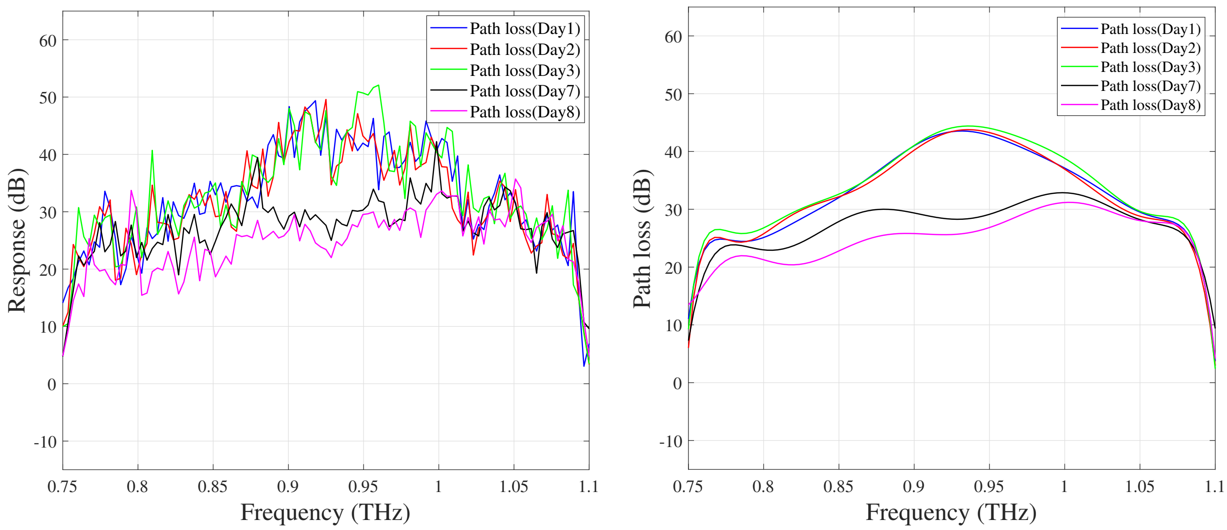
For the transmission response measurements, one sample was considered because all other samples showed a similar



(a) Transmission response

(b) Curves fitting

Fig. 4: Transmission response of sample slice with days.



(a) Path loss

(b) Curves fitting

Fig. 5: Path loss response of sample slice with days.

decaying pattern whilst determining the moisture content. Hence the behaviour of one only sample was analyzed over the frequency range from 0.75 THz to 1.1 THz.

The results as shown in Fig. 4 demonstrated that difference in transmission response was not very prominent in first three days due to less difference in moisture content as mentioned in Table I. However, on day 7 and 8, samples showed a distinct variation in transmission response indicating the substantial loss in moisture content comparing from day 1 to 3. Thus the loss in transmission response of pears samples with passing days reflecting a possibility of any pesticides produced at molecular level due to the evaporation of moisture content in samples. In addition, the path loss of sample was also obtained over the course of seven days measurements as shown in Fig. 5. It also illustrated that loss occurred on day 7 and 8 was clearly high comparing from day 1 to 3. This considerable loss on day 7 and 8 exhibited that the sample was completely dried out and chances of pesticides could be very high at this stage. The sample showed a deep transmission in the frequency range of 0.85 to 1.1 THz reflecting more sensitive and perceptive frequency range. Furthermore, the results were also obtained by applying the fitting curve as shown in Fig. 4(b) which further illustrated the difference clearer from the third day to the eighth day as the MC of the slice was lower than 50% as shown in Table I. These observations can be proven significant for further study of characterization of fruits in the THz region because of strong and important correlation between transmission response and absorption index of materials.

Fig. 5(a) shows the path loss of the same location in sample slice 2, which can be seen that much loss has occurred during the first day to the third day due to the sensitivity of the THz radiation to the high moisture content.

IV. Conclusion

In this paper, it was mainly aimed to highlight the importance and advancements of terahertz technology to detect the moisture content of the pear slices by applying a novel and non-invasive technique. For this purpose, moisture contents of samples were obtained over the course of seven days. In addition, transmission and path loss response was also achieved using the THz wave employing VNA-based techniques with Swissto 12 system in the frequency range from 0.75 THz to 1.1 THz, which can be extended to monitor and control the quality of any other fruits and vegetables. Considering the measurement results, it can be concluded that this novel technique of THz characterization can be captured with the loss of water defined as moisture content which is the obvious phenomenon in the fruits during processing. In the future, through the calculation of the dielectric properties such as permittivity and permeability of the fruits in the THz field, the most important characteristics of fruits can be detected accurately.

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