ARPN Journal of Engineering and Applied Sciences

MICROWAVE REFLECTION MEASUREMENT ON THERMAL DEGRADATION OF ANIMAL AND VEGETABLE OILS

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ABSTRACT

In this work, the reflection measurement on animal and vegetable oils due to different heating temperature was conducted using Agilent E8362B slim probe in conjunction with Agilent E8362B PNA Network Analyzer. The effect of thermal degradation on measured reflection efficient (Γ) is investigated. Many chemical processes are occurred when edible oils are heated during frying process. The thermal degradation products, i.e., volatile and non-volatile chemical compounds are generated. The generated volatile chemical compounds are dangerous to human health. Products of thermal degradation of animal and vegetable oils can be carcinogenic. On the other hand, it may cause diabetes, atherosclerosis, Alzheimer's and Parkinson's diseases, coronary heart disease, sudden cardiac death, and systemic vasculitis. Slim probe and open ended coaxial sensor are implemented to measure the reflection coefficient of the cooking oils. The fresh animal fats and vegetable oils are commercially available in local market. Five types of cooking oil (i.e. corn oil, olive oil, palm oil, sunflower oil and walnut oil) were measured at the temperature of 60ºC, 80ºC and 100 ºC for the frequency range of 3 GHz to 8GHz. When the oil is subjected to thermal degradation during heating, the chemical chain of oil will be altered and resulting in physical and internal properties change. It is the key element that led to the variation of Γ. Γ is function of physical-chemical properties of cooking oil that implying the oil quality. In reflection measurement, there are different noticeable results which indicates the used and fresh cooking oil and the effect of heating period.

Keywords: microwave, reflection, edible oil, thermal degradation.

INTRODUCTION

Frying involves the cooking of food in hot fats or oils. It is usually carried out with a shallow oil bath in a pan over a fire. The food is completely immersed in a deeper vessel of hot oil during the frying process. This method can efficiently transfer heat into the food within short time. Hence, it is a popular method in food preparation in fast food industries [1]. The demand of people lives in urban with busy working life on ready-made deep-fried food is high, especially in developing countries. Hence, the cooking oils has high demand and commercial value. Many restaurants runner reused the used cooking oil by heating it repeatedly to guarantee cost effectiveness.

Reheating cooking oil leads to presence of harmful toxins. Increment of the percentage of trans- fats in reheated oil causes the rancid smell, generation of free radicals, and also some very harmful reactions. Carcinogen can be easily detected in used oil after the high temperature heat treatment. Strictly regulating the reuse of edible oil can help save the domestic as well as restaurant customers from the ill- effects of reheated cooking oil. However, scientific approach needs to be introduced for a reliable gauging system for cooking oil.

Cooking oil can be degraded by heating temperature [2]. The oxidization, polymerization and hydrolyzation of cooking are occurred during frying process or heating with high temperature. [3]. Lipid from oils and edible fats experience thermal degradation in high temperatures or longer heating period [4]. The reused cooking oil that used for frying repeatedly has high tendency to release toxic and carcinogen [2]. Different types of cooking oil exhibit different characteristic based on its composition. However, heating temperature and heating period are the major factors that lead to variation of default characteristic because it degrades the heated cooking oil. The degradation of cooking oil exhibit severe adverse effect to consumers. Hence, it has great motivation to engage this work to investigate the effect of temperature or long heating period on the quality of the cooking oil through electromagnetic method. Cooking oil has the electrical properties [5]. Γ varies with electrical properties of the material, i.e., mismatch impedance that occur due to discontinuity in term of dielectric properties. Thus, Agilent E8362B slim probe is used in this reflection measurement on cooking oils in conjunction with Agilent E8362B PNA Network Analyzer. The reflection measurement was conducted too using an open-ended coaxial sensor.

VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

METHODOLOGY

Sample Preparation

Five samples of oil are commercially available in local market as shown in Figure-1. There are five different types of cooking oil which consist of cornoil, palmoil, olive oil, walnut oil and sunflower oil. The compositions of the cooking oils can be found in the label of product.

Figure-1. Collect edible oils in local market as sample.

The collected sample was placed in the cubicle. Then, the weight was measured using electronic balance before it was heated using the oven. Every oil sample and fat (chicken fat and bone tallow) is 35g and 10g, respectively.

The initial temperature of oven is maintained at 60ºC for 10 minutes. Next, the sample is heated at 60ºC, 80 ºC and 100 ºC for 30 minutes. Then, the heated sample is cooled to room temperature and ready for measurement. The similar steps are applied for each sample.

Reflection Measurement

The open-ended coaxial probe is made of an RG-402 semi-rigid cable. During reflection measurement, the tip of probe is immersed in sample, since the sample under test (oil) is liquid in this work. Figure-2 shows the coaxial probe method and Figure-3.7 shows the open-ended coaxial probe i.e., slim probe used in measurement.

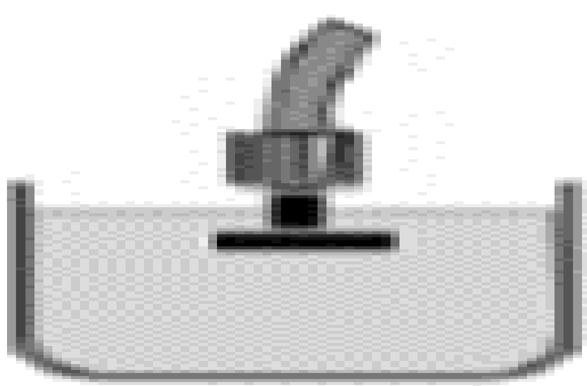


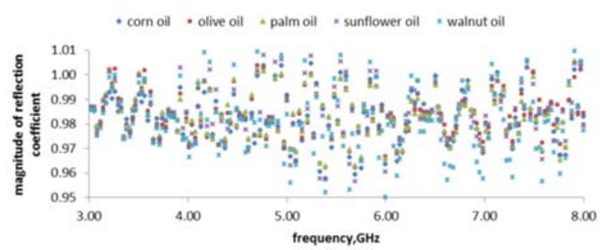
Figure-2. open-ended coaxial probe in measurement.

Reflection coefficient is measured in terms of magnitude and phase using Agilent PNA network analyser, an open-ended coaxial sensor, a pair of retorts stand and 85052 D 3.5 mm economy calibration kit. Calibration needs to be conducted prior to measurement, in order to reduce the systematic error. The measurement was conducted within 3GHz -8GHz because it is operating frequency of probe.

RESULTS AND DISCUSSIONS

Reflection Measurement on Cooking Oil at Room Temperature

Figure-3 illustrate the frequency dependence of reflection coefficient's magnitude and phase for cooking oils at room temperature in the linear format for open ended coaxial cable. Figure-3(a) shows the value of reflection coefficient from P- series network analyzer (PNA) within the frequency range of 0.2GHz to 20GHz. Figure 3(a) visibly shows that magnitude of the oils has a similar pattern of trend line over the frequency. It does for phase as shown in Figure-3(b). The magnitude shows ripple form from 4GHz to 20GHz, whilst the magnitude is scatter over frequency. It shows the weak correlation among oils for the magnitude measurement using open ended coaxial probe. It is due to multiple wave reflection between the extended inner conductor and cooking oils [6]. Meanwhile, the phase response in Figure-3(b) is due to the different time delay between incident wave and reflected wave for each cooking oils. The negative phase indicates reflected wave lag behind incident wave, and vice versa for positive phase.



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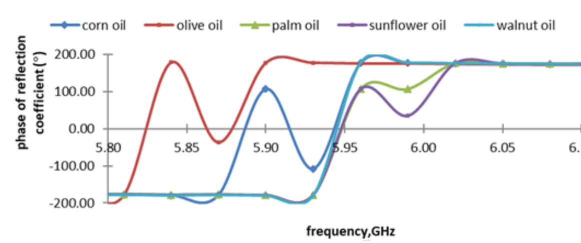

(b)

Figure-3. The variation of (a) magnitude and (b) phase of Γ over frequency for various cooking oils at room temperature.

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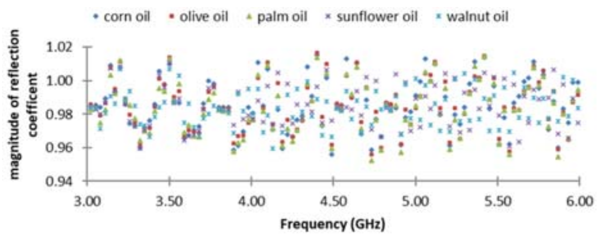
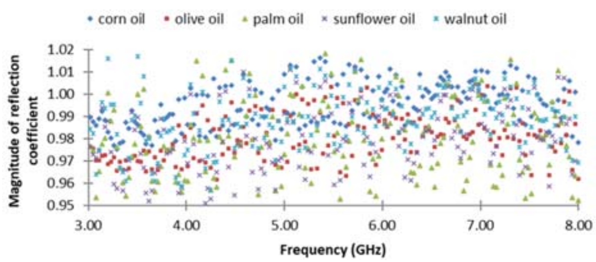
Reflection Measurement on Heated Cooking Oil with 60 ºC, 80 ºC and 100 ºC



(a)



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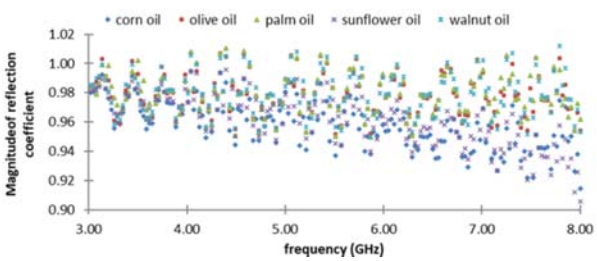
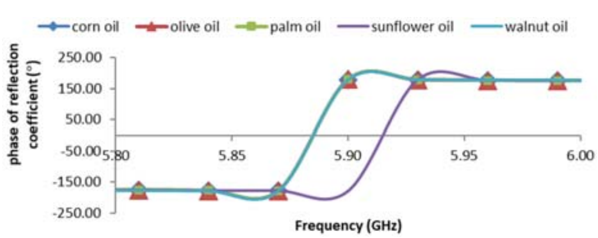


(c)

Figure-4. The variation of magnitude, |Γ| of Γ over frequency for various cooking oils at (a) 60 ºC, (b) 80 ºC and (c) 100ºC.

Figure-4 indicates that the frequency dependence of reflection coefficient's magnitude for cooking oils at temperature of 60ºC, 80ºC and 100ºC. At 60ºC and 80ºC, |Γ| is scatter over frequency for the all sample. It might be due to the multiple wave reflection between the surface of the sensor and cooking oils. At 100ºC, |Γ| of all samples decrease over frequency. As the frequency increases, the |Γ| decreases. The |Γ| decrease significantly for corn oil and sunflower oil.



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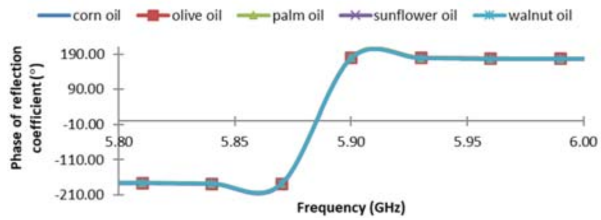

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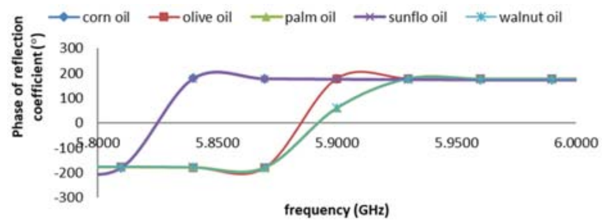
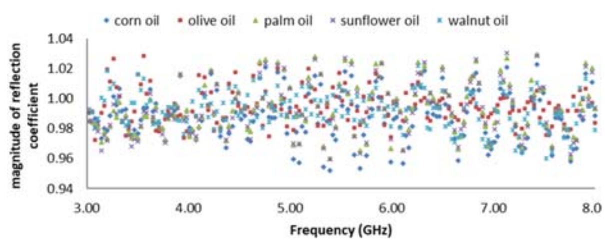


(c)

Figure-5. The variation of phase of Γ, φ over frequency for various cooking oils at (a) 60ºC, (b) 80ºC and (c) 100ºC.

Figure-5 indicate the frequency dependence of φ for cooking oils at temperature of 60ºC, 80 ºC and100 ºC. The difference in φ for the oil samples also can be seen at particular temperature. At higher temperature (100 ºC), the φ for each oil can be seen clearly rather compare with lower temperature(<100 ºC). The variation of the cooking oil's φ maybe due to the delay time between the incident and reflected wave.

Reflection Measurement on Cooking Oils that Heat with Chicken Fat at 60ºC, 80ºC and 100ºC.



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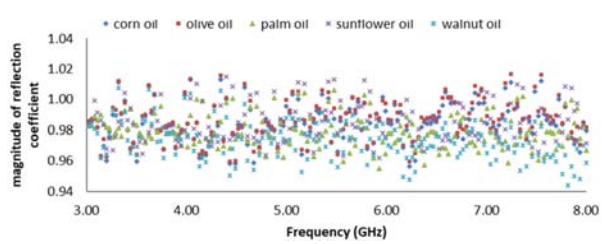

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VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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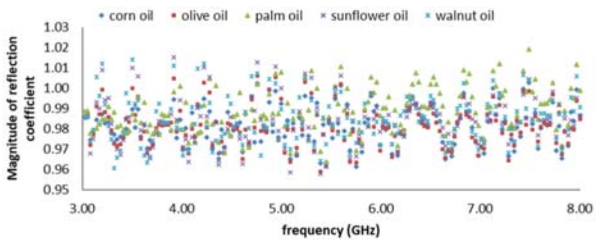
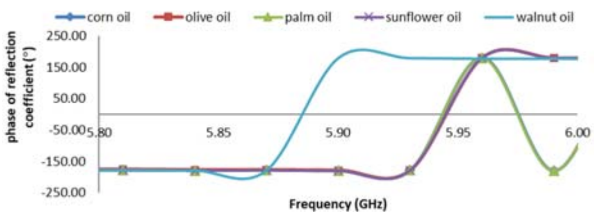


(c)

Figure-6. The variation of magnitude, |Γ| of Γ over frequency for various cooking oils that heat with chicken at (a) 60ºC, (b) 80ºC and (c) 100ºC.



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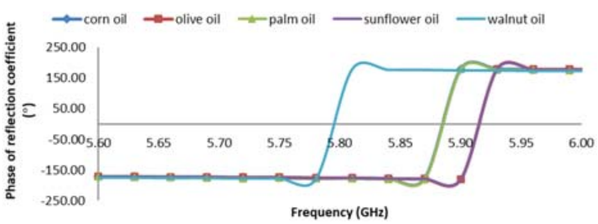

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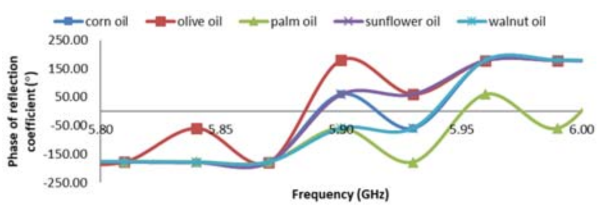
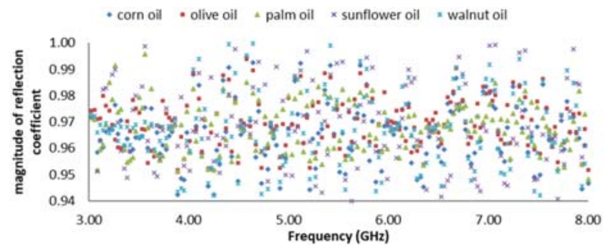


(c)

Figure-7. The variation of phase of Γ, φ over frequency for various cooking oils that heat with chicken fat at (a) 60ºC, (b) 80ºC and (c) 100ºC.

Figure-6 and Figure-7 shows relationship between Γ and frequency, where the temperature of cooking oil is 60°C, 80°C and 100°C within 3GHz to 8GHz. The |Γ| vary over frequency and temperature. At 60°C and 100°C, |Γ| exhibit scattered pattern from 3GHz to 8GHz for all the oil samples. This observation might be due to the undesired environment error as coaxial probe has limited accuracy under some condition. Variation of φ can be seen clearly in Figure-7 at 100°C. The difference of φ is most probable due to time delay between incident wave and reflected wave.

Reflection Measurement on Cooking Oils that Heat with Beef Tallow at 60°C, 80°C and 100°C



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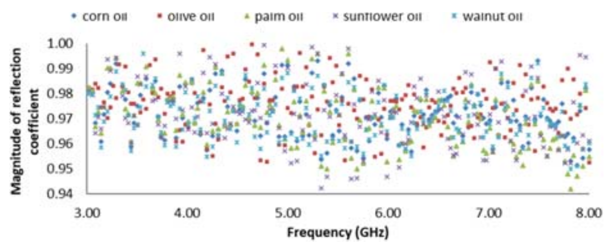

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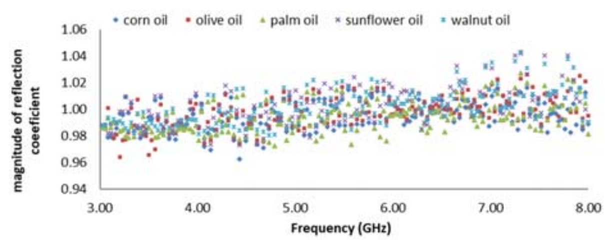
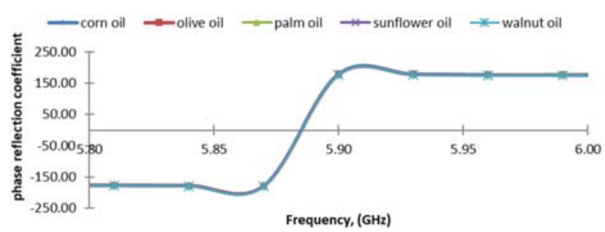


(c)

Figure-8. The variation of magnitude, |Γ| of Γ over frequency for various cooking oils that heat with beef tallow at (a) 60ºC, (b) 80ºC and (c) 100ºC.



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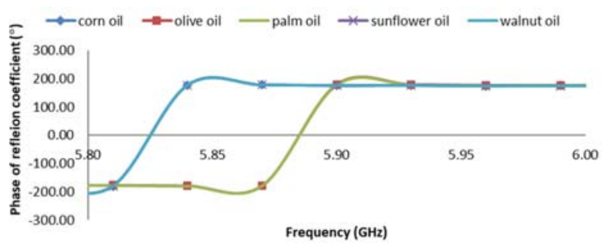

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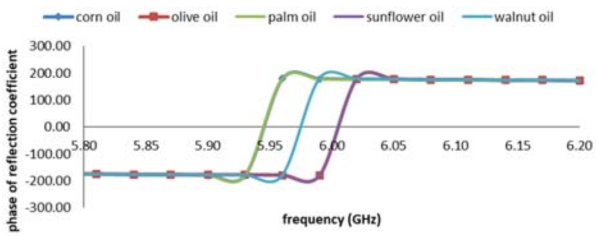

(c)

Figure-9. The variation of phase of Γ, φ over frequency for various cooking oils that heat with beef tallow at (a) 60ºC, (b) 80ºC and (c) 100ºC.

Figure-8 and Figure-9 show the frequency dependence of |Γ| and φ for the cooking oil that heat with beef tallow at 60ºC, 80ºC and 100ºC. At the higher temperature, the |Γ| vary consistently with frequency. It happens is due to the higher amount of saturated fatty acid in beef tallow than chicken fat. When the incident wave interacts with saturated fat in beef tallow, no phase change upon reflections can be seen through Figure 9 at 100ºC.

CONCLUSIONS

The main intention for this research is to distinguish the fresh and used cooking oil and investigate effect of heating cooking oil through reflection measurement. The results provide a fundamental knowledge on electrical properties to judge quality cooking oil. There are some factors that differentiate the performance between cooking oil such as characteristic of cooking oils. In this research, the cooking oil can be classified based on the origin of the cooking oil via reflection measurement. The presence of other substances, e.g., fats in the cooking oil during the heating process led to the variation of electrical properties and characteristic of the cooking oil when it is subjected to time-varying field.

ACKNOWLEDGEMENT

The author would like to acknowledge the support from the UniPRIMA under a grant number of 9001- 00710 & 9002-00146 from the Ministry of Higher Education Malaysia.

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