Distinguished identification of halal and non-halal animal-fat gelatin by using microwave dielectric sensing system

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Abstract: Halal has been a long-disputed issue due to the reason of its complexity consequently of swift advancement in innovation and technology. Gelatin plays a vital role in modern food processing as it has been used in many food preparations and is commonly used to make the pharmaceuticals capsule these days. In this work, various types of animal fat will measure dielectrically to distinguish them for the development of the detection system. This project applied the measurement of reflection coefficient by using the high-temperature probes. These probes use the principle of microwave method and allow the measurement to be made in a fast and non-destructive way. For this project, the high-temperature probe is used to measure the sample of animal fat for instance chicken, beef and pork fat. The fresh animal fat was used and the moisture content of the animal fat was manipulated by using the oven-drying technique. The different levels of moisture content inside the fat will affect the measurement value of reflection coefficient as the moisture content will change the dielectric properties of the animal fat. The measurement of reflection coefficient was made with a network analyzer in the frequency range of 0.2 GHz to 20 GHz. From the experimental result, it can be concluded that pork fat shows distinguishable trend compared with chicken and beef fat which perform
similar trend in variation of reflection coefficient ($|S_{11}|$), dielectric constant ($\varepsilon$) and dielectric loss ($\varepsilon'$) throughout the frequency range from 0.2 GHz to 20 GHz.

**Subjects**: Food Science & Technology; Food Engineering; Food Biotechnology; Food Chemistry

**Keywords**: Halal; dielectrically; reflection coefficient; high temperature probe

### 1. Introduction

Nowadays, many people are concerned about their health and are taking supplements such as Vitamin E or fish oil and the list goes on in order to increase the immunity of their body and make them stronger (Ab Halim et al., 2014). Hence, the soft gel capsules will probably be encountered. These capsules have an appealing look and a smooth finish that make them easier to swallow. According to Capsugel, a major manufacturer of capsules, most soft gel capsules are made from gelatin (Gmia, 2012). The word gelatin is taken from the Latin “gelatus” which means rigid or frozen wherein the main sources are from animal skin especially pigskin and lard (Mohd Salleh et al., 2013). Due to this fact, gelatin capsules are not suitable to be taken by people who hold a strong religious value that prevent consuming certain animals for certain religious reasons (Smith et al., 2011).

Lately, in May 2014, Malaysia Health Ministry announced that pig DNA is identified in samples taken from Cadbury’s Dairy Milk Hazelnut and Dairy Milk Roast Almond products, and shockingly spark uproar and create chaos among local Muslim groups. Following the incident, some Muslims might address lingering doubts over Cadbury’s product while some of the radical Muslims might start hesitating about the halal certification and halal status for the products that are predominantly approved by Malaysian Islamic Development Department (JAKIM). Owing to that, more than 20 Malay-Muslim groups have asked for a nationwide boycott on all Cadbury products, claiming that a holy war needs to be instigated against the confectionery for allegedly attempting to “weaken” Muslims in Malaysia (The Malays Mail Online, 2014). Besides the Cadbury chocolates, other products proclaimed to contain pig DNA include Pure Creamery Butter-Golden Churn butter used in Sarawak’s layer cakes. The Sarawak Islamic Religious Department’s finding on 19 July 2011 left a vast impact on the industry as the butter’s manufacturer, Switzerland-based Ballantyne Food, admitted its products contained pig DNA (The Malaysian Insider, 2014).

Furthermore, Director of The Federation of Malaysian Consumers Associations (FOMCA), Mohd Yusof Abdul Rahman stated that the major problem in Malaysia is that many users do not bother attitude about the products they are purchasing. Yet, they are not sensitive enough and only received medication prescribed to them. Hence, FOMCA has collaborated with the Ministry of Health (MOH) to provide “Know Your Medicines” campaign to ensure consumers are aware of the substance of medications they consume (Pensioen & Blonk, 2010). Subsequent to the campaign, it verified that about 30% of the 100 health products tested in the laboratory of Pharmaceutical Sciences Universiti Sains Malaysia (USM) is not halal as the gelatin capsule originated from pigs. The Dean Prof Dr. Syed Azhar Syed Sulaiman said all the products tested over the last year were sent by the National Pharmaceutical Control Bureau and the product manufacturer to ascertain the source of gelatin that they use. He then added that out of the 100 products that were tested, 30% are unlawful to use gelatin from pork as it is cheaper than beef gelatin (Non-halal Medicine, 2013).

In addition to that, deputy dean of Initiative Studies, IIU Studies Management Centre, Prof Dr. Irwandi Jaswir noted that there is a strong demand for gelatin in the production of various food, health and cosmetics products as Muslim population is getting expanded lately. Nevertheless, it has become a sensitive issue as 95% of the gelatin in the market now is produced from animals prohibited for use by Muslims (The Star Online, 2012). According to the Minister in Prime Minister Department, Dato Seri Jamil Khir Baharom, there are many manufacturers of health products which do not apply
for halal certificate from JAKIM or JAIN (Department of State Religious Affairs) and only 20 supplement product manufacturers and 14 traditional medicine manufacturers obtained halal certificate from JAKIM (Sakina, 2011). There are also very few studies which have investigated the drug, gelatin and alcohol which has been used in Halal pharmaceutical from legal and Shariah perspective which prompts the author to figure out the proper methods for the identification of Halal and non-Halal gelatin due to the momentous demand of Halal products today (Halim et al., 2014).

2. Literature review

الحل in Arabic word means “halal”. Halal is a term assigning any object or an action which is permissible to use or participate in accordance with Islamic law. The opposite of halal is haram, which means illegal or prohibited. Halal and haram are universal terms that apply to all aspects of life. These terms are commonly used with respect to food products, meat products, cosmetics, personal care products, pharmaceuticals, food ingredients, and food contact materials (Herpandi et al., 2011). Islam places a very strong emphasis on cleanliness in everything (Eriksson, Burcharth, & Rosenberg, 2013). As such, before performing their daily prayers, ablution, as a means of cleansing ourselves, is compulsory, and must be performed in the correct manner (Nurdeng, 2009). The concept of cleanliness is also extended to other perspectives especially in the context of food and drink (Audah, 2010).

Thus, it is a fundamental requirement for all Muslims, enshrined in the Holy Quran, for Muslims to eat only that which permissible (Halal) and wholesome (twaibu) (Marzuki et al., 2012). According to The Islamic Council of Western Australia’s Halal Guidelines, Islam has laid down three very significant guidelines on behalf of whether it is dependent on its nature, how it is processed and how it is obtained in the selection of food and drink (Sazelin & Ridzwan, 2011). In accordance with the Quran, the only foods explicitly forbidden are meat from animals that die of themselves, blood, the meat of swine (porcine animals, pigs), animals dedicated to other than Allah (either undedicated or dedicated to idols), animal that has been strangled, beaten (to death), killed by a fall, gored (to death), or savaged by a beast of prey (unless finished off by a human), animal meat over which Allah’s name is not pronounced, as well as intoxicants and alcoholic beverages (Jenkins, Yip, Melman, Frisella, & Matthews, 2010). Regarding Kremer et al. (2008), Quranic verses which have further information regarding halal foods take account of 2:173, 5:5, and 6:118–119, 121. For instance, consumption of pork and products made from pork is strictly forbidden in Islam and the origin of this prohibition is in Surat al-Baqarah:

*He has only forbidden you what dies of itself, and blood, and flesh of swine, and that over which any other (name) than (that of) Allah has been invoked; but whoever is driven to necessity, not desiring, nor exceeding the limit, no sin shall be upon him; surely Allah is Forgiving, Merciful.*

—Qur’an, Sura 2 (Al-Baqara), ayat 173

Animal fat is a solid form of lipid materials, which is gained from animals (Dopponberg et al., 2010). Chemically, it is composed of triglyceride, which is also known as triacylglycerol (TAG); a chemical composite consists of one molecule of glycerol and three fatty acids (Lim et al., 2011). Most animal fats are some combination of saturated fatty acids, monosaturated fatty acids and polyunsaturated linoleic acid and linolenic acid (Mariod, Bushra, Abdel-Wahab, & Ain, 2011a). In most cases, animal fats such as lard and tallow have roughly 40–60% saturated fat and remain solid at room temperature (Pensioen et al., 2010). Dielectric spectroscopy measures the electric and dielectric properties of a substance as a function of the frequency domain. It occurs due to the interaction of an external electric field with electrical dipole moment and the charges of the medium (Stanley, 2010). It is vital as it provides bunches of information about the atomic and molecular motions besides the relaxation processes. It offers certain advantages over some conventional techniques used to study the electrokinetic properties of colloidal particles. Microwave is sort of electromagnetic wave within a frequency range of 300 MHz to 300 GHz. By
referring Equation (1), the frequency $f$ is connected to a corresponding wavelength $\lambda$ by the velocity of light $c$ (Yarmand et al., 2011).

$$c = \lambda f$$

(1)

In practice, not all the microwave band is used for microwave heating applications; in fact, there are some distinct frequency bands which have been reserved from telecommunication applications for industrial, scientific and medical (so-called ISM) applications (Yarmand et al., 2011).

3. Materials and method

The methodology can be referred to as theoretical analysis of the methods appropriate to a field of study, and it includes a body of practices, procedures and rules. There are five steps in this section:

3.1. Sample preparation

Fresh animal fat for instance chicken, beef and pork fat should be used for the experiment. Freezing fat is not suitable to be used because the water contained in the fat will form a crystalline structure that will affect the value of dielectric properties and disturb the microwave measurement. The animal fat was sliced into small pieces and was weighted before and after drying. The samples that we prepared for the whole experiment are approximately 7 gram (g). To make sure the samples are approximately 7 g, digital weight scale is used for this case. The technique of oven-drying method was used to manipulate the moisture content inside the animal fat (Sucipto, Irawati, & Fauzi, 2011). The actual moisture content of the sample fat was first determined by using the wet basis formula in Equation (2).

$$\%m.c = \frac{M_a - M_b}{M_a} \times 100\%$$

(2)

$m.c$ = moisture content

$M_a$ = Mass of the sample after drying in the oven for certain temperature

$M_b$ = Mass of the sample which is totally dried

3.2. Calibration

The calibration of reflection measurement begins with the connection of the coaxial cable to the port 1 of the PNA network analyzer. For coaxial cable, the software used to calibrate is 85052D. First of all, open the software and choose the calibration wizard. In the calibration wizard, types of calibration kit are listed for instance “OPEN”, “SHORT”, and “LOAD”. It sequentially starts with “OPEN”, “SHORT” and lastly “LOAD”. For calibration of dielectric measurement, steps are initiated by selecting “Perform Calibration” and then leave the probe to air. Subsequently, the probe is connected to a shorting block. After disconnecting the shorting block, it is proper to immerse the probe into 25°C temperature water and finally, it comes to the end of the calibration.

3.3. Sample measurement

To take the measurement in an exact accurate method, the entire surface of the sensor must be touching the fixed location of the sample. Different locations of the sample will have different dielectric properties hence we need to adjust and set the proper location of the fat sample. It is appropriate to ensure the sample has no air gap or any oil accumulated within the fat that will affect the measurement result.

3.4. Data acquisition

Data acquisition is a process of sampling the signals that measure the sample and converting the results into a digital numeric value that can be manipulated by a computer. In this project, the P-series Network Analyzer will produce the analog waveform of the measurement. After that, the data-acquisition system in the software will convert analog waveforms into a digital value for further processing. The data obtained from the PNA is the reflection coefficient ($S_{11}$) within the
frequency range that has set earlier, which is from 0.2 GHz to 20 GHz. After reflection ($S_{11}$) and dielectric measurement, the numeric value of the result displayed in the screen can be saved in .prn format.

3.5. Data visualization and analysis
This method is to visualize the data obtained from PNA Network Analyzer which is then demonstrated in Microsoft Excel 2007. The data of the reflection coefficient ($S_{11}$) in a certain frequency range is plotted to explain the relationship between the Linear Mag at different moisture content. Data visualization can also be used to describe the phenomena occurred in the fresh animal fat sample.

4. Results and discussion
At ambient temperature, pork fat shows distinguishable compared to chicken and beef fat as shown in Figure 3. On the contrary, chicken and beef fat show an obvious decrement in dielectric constant value over frequency demonstrated in Figures 1–2. However, the pork fat does not show a noticeable decrease in dielectric constant value along the frequency. Besides, pork fat shows distinguishable where the value of the dielectric loss is lower compared with chicken and beef fat. It can be explained that pork fat has a low energy loss.

For Figure 4, the overall result shows a descending order. As the percentage of moisture content increases, the value of the measured reflection coefficients decreases. It also demonstrates that the value of reflection coefficient decreases when frequency increases. The value of $|S_{11}|$ decreases significantly for three moisture content above 89%. This is due to the effect of free water molecules. At high-water content, the effect of water molecules becomes obvious hence $|S_{11}|$ shows obvious decrement for moisture content above 89%. Figures 5–6 illustrates that both dielectric constant ($\epsilon$) and dielectric loss ($\eta$) of chicken fat shows increases linearly with increasing moisture content. It is because of the dipole rotation of the water molecules (Nishkaran, 2002). Water molecules have a tendency to polarize and able to store energy hence it will induce the increasing value of dielectric constant ($\epsilon$). Meanwhile, the dipolar polarization in the microwave frequency is the contributing factor of dielectric loss which is due to the orientation of water molecule with the imposed electric field (Nelson et al., 2000). In spite of this, both Figure 5(a) ($y = 5.394 x + 1.716$) and Figure 6 (a) ($y = 2.060 x + 0.448$) has steeper gradient compared to other frequencies, which indicates dielectric constant ($\epsilon$) and dielectric loss ($\eta$) is more sensitive to variation of moisture content at frequency 1 GHz.

Figure 7 shows that as the moisture content percentage increases, the reflection coefficient value decreases when frequency increases. The moisture content exceeds 80% shows obvious decrement from 2 GHz to 20 GHz, and the pattern shows consistency while moisture content before 80% shows ripple form from 5 GHz to 20 GHz. Figures 8–9 shows increase in $\epsilon$ value, and it shows contrast phenomenon where $\eta$ decreases with increasing moisture content at 1 GHz and 2.45 GHz. The result of measurement proves that the ionic conductivity dominated in the region less than 3 GHz while above 3 GHz, the dipole orientation of the water molecules become dominant. However, at frequency

![Figure 1. $|S_{11}|$ versus frequency (Ambient Temperature).](image-url)
Figure 2. ε versus frequency (Ambient Temperature).

Figure 3. ε versus frequency (Ambient Temperature).

Figure 4. |S₁₁| versus frequency (Chicken fat).

Figure 5. Variation of dielectric constant with the percentage of moisture (% m.c) at (a) 1 GHz, (b) 2.45 GHz, (c) 5 GHz, (d) 10 GHz, (e) 15 GHz and (f) 20 GHz (Chicken fat).
Figure 6. Variation of dielectric loss with the percentage of moisture (% m.c.) at (a) 1 GHz, (b) 2.45 GHz, (c) 5 GHz, (d) 10 GHz, (e) 15 GHz and (f) 20 GHz (Chicken fat).

Figure 7. $|S_{11}|$ versus frequency (Beef fat).

Figure 8. Variation of dielectric constant with the percentage of moisture (% m.c.) at (a) 1 GHz, (b) 2.45 GHz, (c) 5 GHz, (d) 10 GHz, (e) 15 GHz and (f) 20 GHz (Beef fat).
5 GHz to 20 GHz, dielectric constant ($\varepsilon$) and dielectric loss ($\epsilon$) increase linearly with increasing moisture content. Figure 10 shows that as the percentage of moisture content increases, the reflection coefficient decreases along the frequency range. The moisture content above 65% shows obvious decrement compared to other percentages of moisture content. Besides that, the moisture content below 65% shows severe repel form while moisture content above 65% shows a consistent decrease of $|S_{11}|$ value when frequency increases. Figures 11–12(a–f) are independent study and it is observed that Figures 11–12(d–h) is not linearly presented which infers that there is more than one factor that dominates the relationship of dielectric constant ($\varepsilon$) and dielectric loss ($\epsilon$) with moisture content.

In the dielectric constant aspect, frequency 0.2 GHz exhibits the best sensitivity of the sensor as the gradient value is incredibly high (28.63) among Figure 11(a–c). Besides that, 0.2 GHz also shows better linearity as it has a higher coefficient of determination; $R^2 = 0.858$ compared to 0.6 GHz and 1 GHz. In terms of dielectric loss, it visibly shows that 0.6 GHz exhibits the higher gradient value which is 7.108, illustrating that it has superior performance in terms of sensitivity of the sensor. In addition, at frequency 0.6 GHz as well, it has a higher linearity of graph compared to Figure 12(a–c) where the $R^2$ value is 0.838. Figures 11–12(d–h) which range from 2.45 GHz to 20 GHz are not linearly presented. It can prove that in term of dielectric constant at 0% to 45% of moisture content, 5 GHz displays the supreme performance in terms of higher sensitivity as well as higher linearity. In terms of dielectric loss, 2.45 GHz illustrates the ultimate result in terms of higher sensitivity and linearity.

5. Conclusion

From the experimental result, it can be concluded that pork fat shows distinguishable trend compared with chicken and beef fat which perform similar trend in variation of reflection coefficient ($|S_{11}|$),
dielectric constant ($\varepsilon$) and dielectric loss ($\delta$) throughout the frequency range from 0.2 GHz to 20 GHz. At ambient temperature, in terms of dielectric constant and dielectric loss, pork fat displays lower $\varepsilon$ and $\delta$ than chicken and beef fat from 0.2 GHz to 20 GHz. For the variation of reflection coefficient ($|S_{11}|$) with moisture content, pork fat exhibits a distinguishable trend compared with chicken and beef fat at 5 GHz, 10 GHz and 20 GHz. Relationship of $|S_{11}|$ and moisture content for pork fat is not linearly presented while chicken and beef fat both display linearly increasing of $|S_{11}|$ value when moisture content.
increases at 5 GHz. In terms of dielectric constant ($\varepsilon$) versus moisture content, pork fat is clearly distinguishable compared with chicken and beef fat at 2.45 GHz, 5 GHz, 10 GHz, 15 GHz and 20 GHz. Both chicken and beef fat illustrate the increasing $\varepsilon$ along the increasing moisture content from 2.45 GHz to 20 GHz while pork fat is not linearly presented at 2.45 GHz and 5 GHz. Apart from 1 GHz, at 2.45 GHz, 5 GHz, 10 GHz, 15 GHz and 20 GHz, both chicken and beef fats display similar trend which increases linearly along the increasing moisture content while pork fat is not linearly presented in the variation of $\varepsilon$ and moisture content. It can be explained that there is more than one factor that dominates the relationship of $\varepsilon$ with moisture content in pork fat.

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