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DIELECTRIC SPECTROSCOPY ON MIXTURE OF RICE HUSK, RICE HUSK ASH AND RICE BRAN FROM 4 Hz TO 1 MHz

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ABSTRACT: In this study, mixtures of rice husk/rice husk ashes (RHA) with RB on different ratios were prepared. Dielectric permittivity (ε'), loss factor (ε'') and AC conductivity (σ') were measured in the frequency range of 4 Hz to 1 MHz in ambient temperature. Results for mixture of RHA and RB indicate that a dipolar relaxation occurring between $10^3 - 10^5$ Hz and the peak is depressed and shifted to lower frequency as the RB content increases in the mixture. Moreover, AC conductivity decreases as the RB content increase. This may attributed to production of natural oil content from RB. In contrast, a dielectric characteristic for RH is generally not affected by the RB contents. This study explore dielectric characteristic of mixture between RH/RHA and RB in low frequency range because lack of literature is reported on low frequency response. Additionally, the potential application of RH/RHA and RB could be explored in effort to diminish waste disposal and enhance environmental protection.

Keywords: Rice Husk, Rice Bran, Dielectric Permittivity, Dielectric Loss Factor, Frequency

1. INTRODUCTION

The commercial rice-milling process produces approximately 120 million tons of raw rice husk (RRH) [1] and 76 million tons of raw rice bran (RRB) in the world annually [2]. However, the production of rice by-products increase due to the growth of demand for rice from year to year in sequence of the population growths in Africa and Asian countries [3]. The main compositions in RRH are silica, cellulose and lignin [1], while fresh RRB is rich of micronutrients like oryzanols, tocopherols, tocotrienols, phytosterols, 20% oil and 15% protein, 50% carbohydrate dietary fibers. However, the natural oil content can be easily degraded to glycerol and free fatty acid by lipase enzyme which cause a rancid smell [4]. This lipases hydrolyze process is endogenously produced as a result of microbial activity during the milling process [5].

Hence, less commercial interest and low nutrition value render the RRH and RRB are being discarded which is either burnt or dumped as waste or utilized for non-energy related low value applications, e.g. animal roughage [6], mulching [7] and bedding materials [8] by majority of rice producing countries. Such improper disposal methods constitute to land detriment and air pollution that violates environment protection legislation.

These works turn this liability into asset by determining the dielectric properties of RH, RHA and RB in order to find possible utilization in the electrical industry. Moreover, this study would extend the knowledge of dielectric characteristic of RRB, RRH, and mixture between RHA and RRB in low frequency range since available information on low frequency response is very scarce in the literature.

2. METHODOLOGY

2.1 Samples Preparation

RRH and RRB used in this work were supplied by a local rice milling factory at Perlis, Malaysia. After removing clay and rock, the RRH was milled into 0.03 mm particle size using a RT-34 pulverize machine. Next, the grinded RRH was incinerated at a controlled temperature of 500°C for 3 hours and cooled in 1 hour by using muffle furnace. Next, the obtained RHA was ground and mixed with RRB at different contents. A disk-form pellet with 13 mm diameter was formed by using hydraulic press model 769YP-15A. The composition of pellets in this study is listed in Table 1 with the designation for the respective mixture fraction.

2.2 X-ray Diffraction Analysis

The amorphous phases of the RRB, RRH, and RHA were identified by XRD analysis, Bragg angle 2θ in angular range of 10° to 80° at 5°/min in steps of 0.02 with Cu-Kα radiation. Model of X-ray Diffractometer is XRD-6000 (Shimadzu, Japan).

Table 1 Mixture fraction of the RRH, RHA and RRB.

Sample Code	Weight (±0.001 g)	
	Rice Husk	Rice Bran
RRB	-	0.600
RRH	0.600	-
H500B0	0.600	-
H500B1	0.500	0.100
H500B3	0.300	0.300
H500B5	0.100	0.500

2.3 Dielectric Measurement

Dielectric measurement was performed at room temperature by using HIOKI IM 3570 with L2000 4-terminals probe in the frequency range of 4 Hz to 1 MHz with an oscillation voltage of 1.0 V.

3. RESULTS AND DISCUSSION

The XRD spectrums of RRB, RRH and RHA on 500 °C combustion temperatures are shown in Fig. 1. It presents a broad baseline at around 22° which means those materials has significant content of amorphous compounds. As reported by [9], RHA is very sensitive to the combustion temperature and time duration in a furnace. The appearance of RHA is white colour indicating the residual carbon content is low.

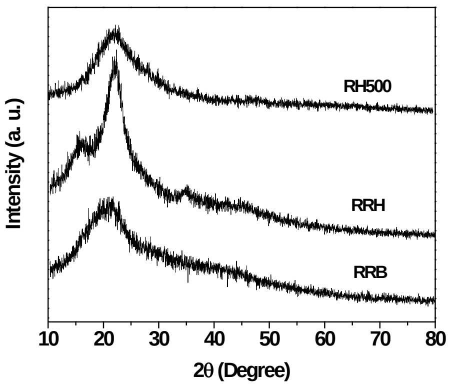

Fig. 1 X-ray diffraction pattern of RRB, RRH and RHA after thermal treatment made at 500 °C.

Dielectric properties are important in predicting the behavior of the materials when they are subjected to the low frequency electric fields in order to design component for the application of microelectronics, optoelectronics and cryoelectronics [10]. The dielectric properties of usual interest in such applications are the dielectric permittivity, ε', and the dielectric loss factor, ε'', respectively the real and imaginary parts of the complex permittivity,

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \quad (1)$$

Basically, the dielectric permittivity represents the polarizability response of a material to the applied field, while the dielectric loss factor represents the energy loss because of the retarding or friction forces of the rotating dipoles during the movement of charges in an alternating electromagnetic field [11].

Figure 2 and 3 show the frequency dependence of the real (ε') and imaginary (ε'') part of the complex permittivity, respectively for the prepared samples measured at ambient temperature.

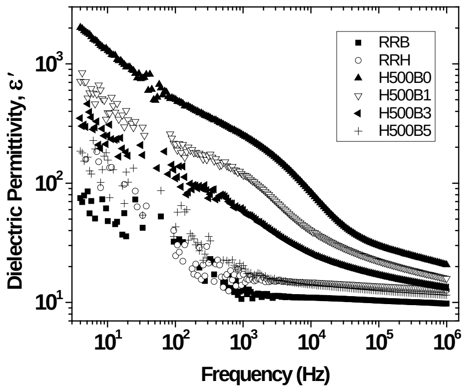

Fig. 2 Frequency dependence of dielectric permittivity of RRB, RRH and mixture of the RHA with RRB at different fractions.

In Fig. 2, it shows an electrode polarization at low frequencies and continuous with a relaxation dispersion around 1 kHz. It can be observed that the dispersive behavior reduced as RB content increase. The sample with the highest RB content, i.e., H500B5 has almost similar trend with RRH and RRB, which exhibit a general plateau above 1 kHz indicating the mobile carriers able to follow the rapid alternation of the electric field. In the meanwhile, a corresponding dielectric loss peak is observed in Fig. 3 where the peak shifts to lower frequency as the RB content increases. This may due to the free fatty acid that content in RB inhabit the movement of mobile carrier and leads to lagging in dipole polarization with respect to changing electrical field. Beyond the loss peak frequency, ω_p the charges cannot oscillate as quickly as the alternating field, dispersion takes place and eventually decrease to a constant value of ε' at higher frequencies. This is due to dipole polarization mechanism ceases to contribute to the net polarization of the dielectric.

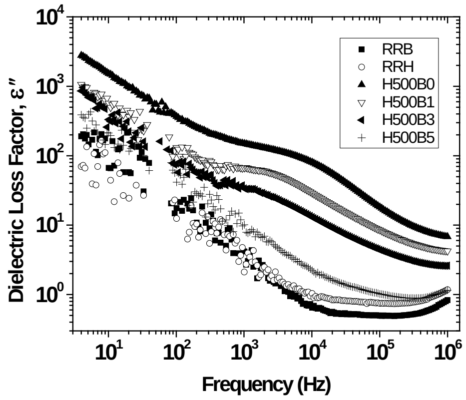

Fig. 3 Frequency dependence of dielectric loss factor of RRB, RRH and mixture of the RHA with RRB at different fractions.

The loss factor of the RRB, RRH and H500B5 decreased with increasing frequency from 4 Hz to 10 kHz, reached a minimum, and then increased as frequencies were further increased to 1 MHz. The dielectric spectrum for RRB are in good agreement with earlier results of [12] in which authors reported the frequency dependence of the ε'' of fresh soybean oil at 25° C. These variations may associate to high content of free fatty acid. Free fatty acid fraction of RRB contained highest oleic acid followed by linoleic acid and linolenic acid [13] [14].

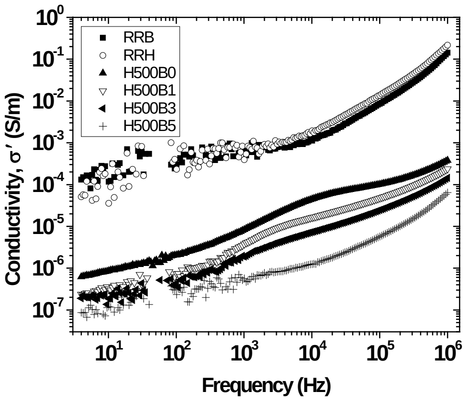

Fig. 4 Frequency dependent of real conductivity of RRB, RRH and mixture of the RHA with RRB at different fractions.

Figure 4 shows the variation of real conductivity as a function of applied frequency for the RRB, RRH and mixture of RHA with different RB content, which calculated from equation as shown below.

$$\sigma' = \omega\varepsilon_{\circ}\varepsilon'' \quad (2)$$

where ω is the angular frequency, $2\pi f$, and $\varepsilon_{\circ}$ is the dielectric permittivity of free space, 8.854×10^{-12} F/m.

As seen in Fig. 4 the present of conductivity disperse at low frequencies is associated with the lack of external force where motion of charges is reduced to weak oscillation within its neighborhood vacant site instead of having long-range transport motion under the influence of an applied field. At higher frequencies, the conductivity spectra exhibit a stronger dispersive region before reach the relaxation frequency, which could be attributed to short-range transport due to motion of mobile carriers over limited distance on short time scales [15] [16]. Beyond the relaxation frequency, further increment of conductivity can be assigned to the fact that mobile carriers vibrates more frequently within the allowed localized sites [16].

Both RRB and RRH have similar trend of conductivity spectra as depicted in Fig. 4. The high conductivity of RRH was contributed by potassium (K), which is metal element that contented at the outer and inner surface of RRH. After combustion process, the potassium content reduced significantly as decomposed [17]. Generally, RRB has high calcium content in addition to micronutrients [18], which may leads to high conductivity characteristic.

Figure 4 also clearly shows that conductivity increase with increases of RHA content. Silica is a major element in RHA [9], [17], [19]-[23] which may react with element calcium from RB, forming a compound with greater insulation properties. The result also indicated that mobile carriers were mainly contributed from RHA. In other words, the amount of mobile carries was subjected to the RHA content. Basically, diffusion coefficient, D and mobility, $\mu = eD/kT$ are connected by Nernst-Einstein relation and lead to conductivity, σ [24]

$$\sigma = \frac{ne^2 D}{kT} \quad (3)$$

where n is charge carrier density, e is carrier charge, k is Boltzmann constant, and T is absolute temperature. Decrement of conductivity with RB contents may correlated with enhancement of activation energy in diffusion for electrical transport process. Activation energy for electrical conductivity can be explained by Anderson and Stuart model [25]. There are two possibilities of hindrance for diffusion mechanism. The conduction pathway being strained and the mobile carriers may induce electrostatic binding energy with other elements within the sample. Hence, diffusion movement of mobile carriers encountered more difficult steps and resulting in an overall decrease of conductivity with the increase of RB content.

4. CONCLUSION

The dielectric permittivity, dielectric loss factor and conductivity with different rice bran content are frequency dependence. From the thorough analysis of the experimental data, short-range transport of carries predominant conductivity spectra and dipolar type relaxation occurs at higher frequency regions as observed in the dielectric loss factor plot. Dielectric permittivity, dielectric loss factor and conductivity decreases with an increase in RB content. Such a behavior may attribute to decrease number of mobile carriers and formed a compound with lower conduction effect. Besides, Anderson-Stuart model has been used to describe the variation of the conductivity by inducing activation energy. This work demonstrates that dielectric properties of RHA can be effectively tailored by mixing RB possessing vary electrical characteristics. In addition, there is a potential to change these abandoned agriculture waste into renewable energy resource for electrical field applications.

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