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RESEARCH ARTICLE

Evaluation of electrical properties of paddy husk and husk ash composites for the possibility of high-end alternative usage

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ABSTRACT

Effort is made to introduce a bio-degradable dielectric material using paddy husk and husk ash. *Oryza sativa* cultivar PUSA 1121 husk (OSH) and ash (OSA) as a highly compressed mixture in specific ratio depicts enough effect of electric field. Relative permittivity of compressed OSH-10, OSH-20, OSH-30 are OSH-40 having 10, 20, 30 and 40% husk ash, respectively are found efficient to act as dielectric materials. Permittivity at different frequencies show relaxing of polarization among dipoles. Variation in permittivity with addition of ash in controlled ratio is modifying the sample enough to be a suitable material. Resistivity, AC conductivity and dielectric loss of OSH-40 is observed more suitable for the application of this bio inspired selected material as capacitor. The relation between applied electric field and polarization effect shown by the dipoles shows the relaxer behavior of the samples, making it suitable for bio- degradable memory devices at ambient temperature. The findings may be useful for the possible application of paddy husk in high-end utilization.

Keywords: Dielectric permittivity, dielectric loss factor, frequency, paddy husk, ash

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INTRODUCTION

Paddy is an important crop of Gramineae (grass family) and classed under genus Oryza. The domesticated paddy has two species as *sativa* and *glaberrima*. Paddy (*Oryza sativa* L.) is the most commonly and widely cultivated semi aquatic, monocot cereal crop (Kumar and Prasad, 2018). The starchy kernel of this plant as rice is used to nourish over half of the worlds' population and thus making it a second most important cereal grain. Rice and rice-based food products are the part of staple diet for majority of Asian population. The production of paddy in India witnessed more than three folds increase in past 50 years. India contributes more than one-fifth paddy production of entire world (Singh and Prasad, 2016). India as a leading paddy producing country in Asian subcontinent and reckoned the production of 172.58 MMT from the crop area of 44.50 million hectare in the year 2018 (FAOSTAT, 2020).

Characteristics of promising paddy varieties as affected by shelling and milling operations are reported (Singh and Prasad, 2013; Bhatia et al., 2010). Pusa 1121 is an Indian Basmati rice variety known for its extra-long slender grains of length up to 8.3 mm. The extent of breakage for extra-long rice kernels are much higher and thus, the degree of milling affects the head

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rice recovery (Prasad et al., 2012). Paddy or rough rice is made edible after removing the husk. Bran and germ are further removed through the milling process to make the rice palatable, digestible, storable, and easy to cook. The rice bran is commonly used to produce rice bran oil while very limited valuable applications are rarely seen in cited literature for the paddy husk. Around 22 % of the weight of paddy is husk. This husk is used mainly as fuel in the rice mills to generate steam for the paddy parboiling (Kaushik et al., 2001). Husk contains around 25 % of mineral matter as ash content, mainly as amorphous silica (85 - 90 %). The generated husk ash finds further limited applications and pose disposal problem. Similarly, the problem of stalk burning in field, a major environmental concern. On other hand risk-free decomposition, safe dumping, and recycling of electric and electronic gadgets are another challenging issue. Although people are trying to overcome these problems, still the problem of e- waste will further increase in coming days.

Thus, under the present work, an effort has been made to utilize the rice husk and its ash in different proportions to characterize its electrical properties so that this bio-degradable an important dielectric materials may find suitable applications and simultaneously solve the present day burning issues.

MATERIALS AND METHODS

Oryza sativa husk (OSH) of cultivar PUSA 1121 was procured from a local rice mill, half of the collected OSH was burnt and allowed to cool at room temperature i.e. *Oryza sativa* ash (OSA). Both OSH and OSA samples were milled in planetary milling machine for four hours, dried in a PID controlled hot air oven for 24 hours at 70±0.5^{O}C. Four combinations of OSH and OSA (Table 1) have been prepared separately as per the following:

Table 1: Samples having *Oryza sativa* husk (OSH) and *Oryza sativa* ash (OSA)

Sample No.	Sample	OSH to OSA Ratio	
		OSH	OSA
1	OSH-10	90	10
2	OSH-20	80	20
3	OSH-30	70	30
4	OSH-40	60	40

Fixed amount of glycerol as binder was used with samples and hand milled for constant time of half an hour. All the samples are further heated for 120^{0}C and kept at this temperature for two hours and further cooled to room temperature. Pellets of 10mm diameter was prepared at the load of 5-ton pressure. The pellets were made conducting by applying silver pastes on both the sides of the pellets. Further, the electrical properties were determined for all the prepared pallet samples.

RESULTS AND DISCUSSION

Frequency and temperature dependent dielectric properties of paddy husk with husk ash in different proportions are acquired using Wayne Kerr Precision impedance analyzer. Impedance of samples are related with resistance used in series, inductive reactance (**X_L**) and capacitive reactance **(X_C)** and expressed as Eqn. 1.

$$Z^2 = [R^2 + (X_L + X_C)^2] \quad \textbf{(1)}$$

By matching of R and X_L, X_C can be determined. Capacitive reactance (X_C) which is the reciprocal of the product of angular frequency and capacitance i.e. $X_C = \frac{1}{\omega C}$. In this way C_m is known and C_0 is the value of capacitance empty space can be determined as

$$C_0 = \frac{\varepsilon_0 A}{d} \quad \textbf{(2)}$$

The ratio of capacitance in given dielectric medium to the vacuum gives relative permittivity.

$$\varepsilon_r = \frac{C_m}{C_0} \quad \textbf{(3)}$$

The temperature dependence of dielectric constant has been studied at variable temperature range from 20^0C to 250^0C and at definite frequency 100 Hz. At the same time frequency dependence of relative permittivity is another aspect of the present work. The reciprocal of tan loos justifies the quality factor of the sample. Analysis of the polarizing capacity of the samples has been further observed by applying electric field of specified range.

The dielectric properties as a function of frequency and temperature are studied using Wayne Kerr Impedance analyzer. As shown in Fig.1, the material has gained dielectric response with increasing of ash concentration as expected. The relative permittivity or dielectric constant (**ε_r**) of each sample was found noticeable. The gradual decreasing trained of **ε_r** is observed with increase in temperature but improvement in dielectric value is noticed at the same time with increase in OSA fraction. The almost same response has been observed (Khor et al., 2016) in the study of rice husk, rice bran and its ash but the value of dielectric has been found better.

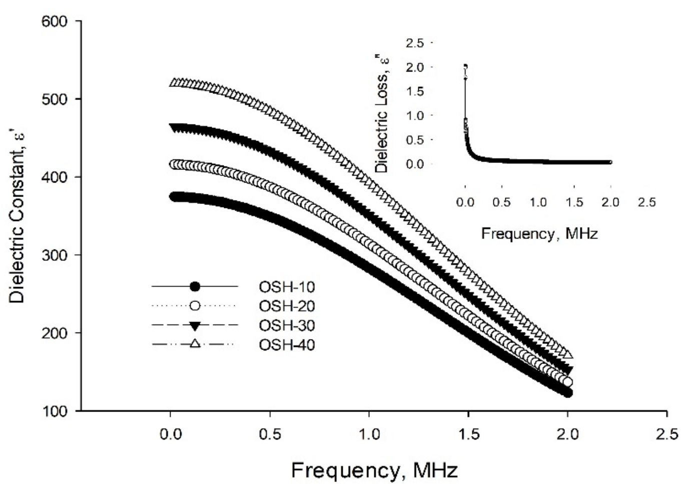

Fig 1: Frequency vs dielectric constant inset dielectric loss

The decline in dielectric value appears faster after 165^0C, 163^0C, 161^0C and 160^0C for OSH-10A, OSH-20A, OSH-30 and OSH-40, respectively (Table-2). The faster decline is reported due the change in hygroscopic state into an hygroscopic state of the samples (Giaquinto et al., 2018). The gradual increase in dielectric value is due change in diffusion rate of OSA material, ultimately the porosity changes and shows its reflection on dielectric value.

Table 2: Conversion temperature as affected by amount of husk ash

OSA Concentration	Conversion temperature
10	165^0C
20	163^0C
30	161^0C
40	160^0C

Dielectric behavior of these samples has been observed in the frequency range 20 Hz to 2.0MHz. The relative permittivity has been found to be in close vicinity at higher frequencies while better at lower frequencies. The polarization exists in all samples although sharp rise is observed with the sample OSH-40 with high OSA concentration. At lower frequencies (up to 0.5 MHz) the dielectric value is almost linear which is making the samples useful for application in low frequency device. Although relative permittivity is significant up to frequency 1.5 MHz. The performance of OSH-40 is once again best among all samples (Fig. 2).

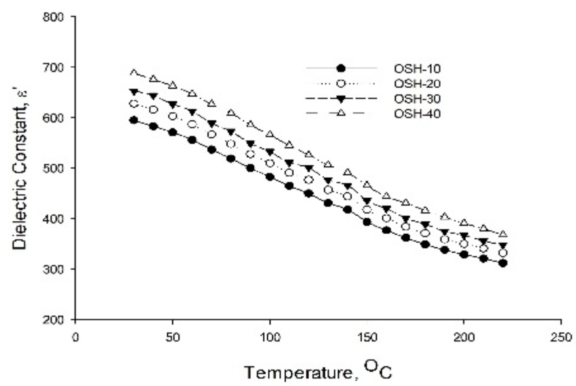

Fig 2: Temperature vs dielectric constant

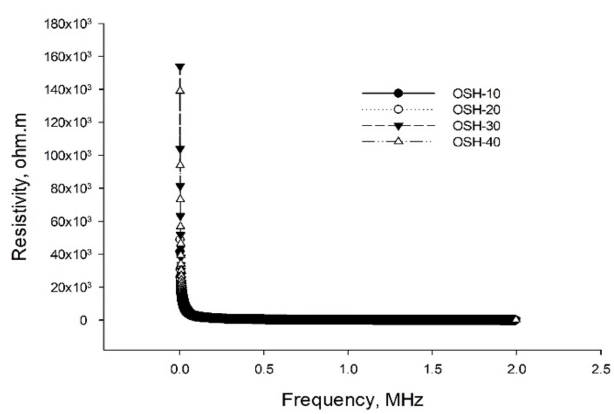

Fig 3: Frequency vs resistivity

As shown in Fig.3, the AC resistivity falls initially for all samples but soon after 100 Hz it remains constant for all the samples. Resistivity of the sample OSH-40 exhibits better resistivity which is signal of having better value of relative permittivity. Although resistivity has been noticed in increasing order with increase in ash concentration. Higher the value of OSA concentration substitutes OSH component which is responsible for the growth in resistivity. The decline in resistivity shows increase in conductivity as the ratio of OSA increases. Clearly shows that conductivity increase with increases of OSA content.

Silica is a major element in OSA (Chen et al., 2015; Bie et al., 2015; Haslinawati et al., 2009; Ismail et al., 2015) which may react with element calcium from OSH, forming a compound with greater insulation properties.

Fig. 4 shows the response of samples to AC flow operated under 100Hz of frequency at room temperature. This is carried out to understand response of samples for being a bio dielectric material. The dielectric loss factor indicates the energy loss because of the retarding or friction forces due to alignment of dipoles during the movement of charges in an alternating electromagnetic field (Haslinawati et al., 2009). Dielectric loss is predominantly high at lower frequency. At higher frequencies, the dielectric loss of each samples has been recorded decreasing slowly which depicts from less slope of the graph (Fig.4). With increase in OSA concentration dielectric loss has been observed decreasing but in case of OSH-40 it is different from others. The loss factor is reported increasing faster with respect to other samples which is making the sample less useful than others. The lower value of tan loss is once again enough to say the utility of the sample as dielectric materials. The dielectric loss factor indicates the energy loss because of the retarding or friction forces due to alignment of dipoles during the movement of charges in an alternating electromagnetic field (Haslinawati et al., 2009). Dielectric loss is predominantly high at lower frequency. At higher frequencies, the dielectric loss of each samples has been recorded decreasing slowly which depicts from less slope of the graph (Fig.4). With increase in OSA concentration dielectric loss has been observed decreasing but in case of OSH-40 it is different from others. The loss factor is reported increasing faster with respect to other samples which is making the sample less useful than others. The lower value of tan loss is once again enough to say the utility of the sample as dielectric materials.

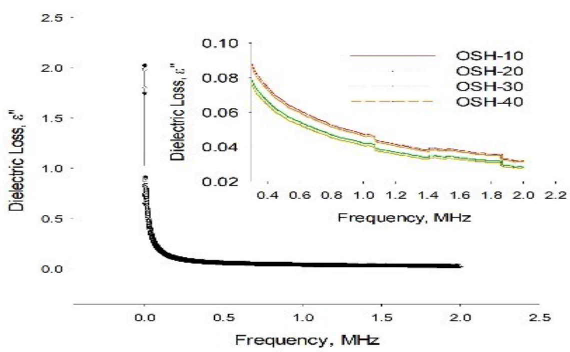

Fig. 4: Frequency vs dielectric loss

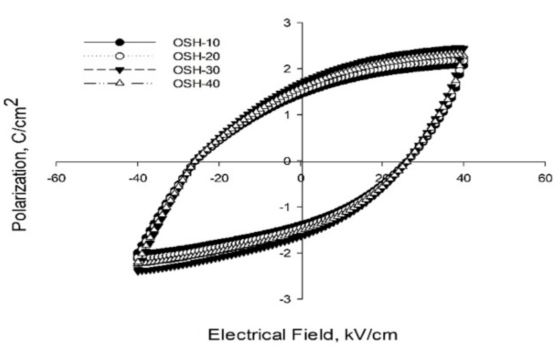

Fig. 5: P-E hysteresis curve

The samples were also put to electric stress to study effects of electric field on any change in dipole orientations and overall polarization of the materials. The results are as shown in Figure 5.

The saturation polarization has been found higher with increasing OSA concentration. The fragmental width of the graph has been noticed with average continuous rise of the order of 8.23% which enables the samples for better results with OSA substitutions. The horizontal stretch in the graph represents the consistent growth in polarization factor. Saturation polarization for each sample OSH-10, OSH-20, OSH-30 and OSH-40 has been observed to be 4.772, 5.164, 5.589 and 6.050 μC/cm^2, respectively. The continuous horizontal stretch in P-E graph refers to rise in electric coercivity (Kumar et al., 2017). Study of overall electrical properties of these samples reveals following facts at glance as in Table 3.

Table 3: Comparative electrical properties

Sample	Dielectric constant at 100Hz	Critical temp. (°C)	Saturation Polarization (μ C/cm^2)	Quality Factor
OSH-10	1071.00	165^{0}C	4.772	Low
OSH-20	1188.81	163^{0}C	5.164	better
OSH-30	1226.29	161^{0}C	5.589	better
OSH-40	1235.93	160^{0}C	6.050	best

OSH-40, where 40% husk ash was used has been proven a bio- dielectric material having significant relative permittivity with least dielectric loss. The relative permittivity has been noticed maximum with lowest dielectric loss for OSH-40, , the combination of which may find the possible high-end application as the capacitor.

CONCLUSION

Focus of present study was to investigate electric properties of biodegradable *Oryza Sativa* husk, a byproduct of rice mill using parameters like permittivity, resistivity, dielectric loss, and electric hysteresis. The output of the work is capable to start a new vision of bio- dielectrics which can turn this liability of dumping a bio waste into asset for charge storage devices. At lower frequencies samples show higher resistivity which supports the fact that at lower frequencies dielectric constant is also higher. At higher temperature resistivity of the samples is observed low but constant over a reasonable range of frequency making the samples better for resonator filters. The materials exhibited rise in saturation polarization with additional ash thus making these bio- degradable samples attractive for memory devices, resonator filters and multi-layered capacitors. The consistent rise of dielectric constant and decline of resistivity indicate formation of samples to be suitable for tunable capacitor also. The electrical properties of dielectric material alter when ash is added. The OSH-40 having 40% husk ash was found to be having highest dielectric constant and least dielectric loss. This property is required to meet the need as a capacitor and may find possible application as bio-electronic items on one hand and solve the burning problems of waste disposal.

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