



Dielectric Properties of Fresh Roma and Cherry Tomato Samples at Different Frequencies and Temperatures

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ABSTRACT

The dielectric properties of two different tomato varieties, Roma, and Cherry, were measured with an LCR meter, at 50 KHz, 90 KHz and 120 KHz frequencies. The measurement was carried out at 35 °C, 45 °C and 55 °C temperature. The tomato samples are obtained from the farm within nine days period, washed and sliced with sharp knife. Two samples of matured and pre-mature, from each of the varieties were used to prepare four fresh samples. The samples were loaded on test cell, connected to an LCR meter. The experimental result show that both dielectric constant and dielectric loss factor decreased with increasing frequency, for all the samples. As the temperature increases, dielectric constant was found to decrease, while the dielectric loss increases, for all the samples. Cherry was found to have higher dielectric constant and dielectric loss than Roma. At 50 KHz, for example, the dielectric constants for Cherry matured are 32.41, 31.68 and 30.44, for Roma matured are 25.66, 24.79 and 23.92, at 35 °C, 45 °C and 55 °C temperatures respectively. While the results also shows that, at 50 KHz, the dielectric loss for the pre-mature samples are 6.41, 7.75 and 8.91, for Cherry and 5.30, 6.10 and 7.57, for Roma, at 35 °C, 45 °C and 55 °C temperatures respectively, which indicated the increase in dielectric loss with increasing temperature. While the dielectric constant and dielectric loss decreases with increasing frequencies.

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INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most important vegetable plant in the world. It originated in western South America, and domestication is thought to have occurred in Central America. Because of its importance as food, tomato has been bred to improve productivity, fruit quality, and resistance to biotic and abiotic stresses. Tomato has been widely not only used as food, but also as research material. The tomato plant has suitable and very interesting features which other model plants do not have. It is rich in health-improving food components such as carotenoid (Lycopene), ascorbic acid (Vitamin C), Vitamin E, foliate and dietary fiber (Davies and Hobson, 1981). Tomato

belongs to the family solanaceae where pepper, potato, tobacco, eggplant and tomatillo Taylor (1986). In Nigeria, Tomato is one of the major and most popular commercial vegetable crops widely grown especially in the Northern part. It is very suitable, in terms of yield and consumption, and it is used all over the world in making different types of dishes including soups, salad, stews, burger etc. It is also used in production of tomato paste, puree, ketchup, tomato juice, and lots of other sauces. It can be produced successfully in Nigeria during the rainy and dry seasons. During the rainy season (June - September), fruit set is often poor, probably due to high temperatures. Shortage of tomato during off season is mainly due to insufficient water.

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Moreover, high temperature and excessive humidity cause tomato to die off and stop setting fruits.

In Nigeria, the consumption of tomato is 10 grams per person in each day, as estimated by Olorunfemi and Ajibefun (2007). FAO (2012) estimated the demand for fresh tomato fruits at 1.785 tons per day or 651,525 tons per annum. Nigeria is also ranked as the 13th country in the global tomato production scale in the year 2017. Nigeria is the second largest production in Africa, according to Ebimeowei and Ebideseghabofa (2013). With an annual production of 2.3 million metric tons, valued around N247,539600,000, while Jigawa State is one of the highest yielding regions in tomatoes production in Nigeria. In the year 2019, Jigawa State Investment Promotion Agency reported that in Nigeria the demand for fresh tomatoes is about 3.5 million metric tons.

Dielectric properties can influence the level of interaction between the food material and high frequency electromagnetic energy. Dielectric properties of food materials, which reflects the interaction and electromagnetic energy are essential for successful design of microwave processing effects of temperature and field frequency. Generally the dielectric property of food material varies with composition, moisture, temperature and frequency (Ryynanen, 1995). The dielectric properties of biological materials include the dielectric constant (ϵ'), which is related to material's ability to store electric energy when subjected to an electric field, and dielectric loss factor (ϵ''), which influence the conversion of electric energy into thermal energy.

Lack of proper methods of preserving tomato in Nigeria, and Jigawa State in particular leads to severe loss of about 750,000 --- 1.3 million tons in Nigeria every year, Ugonna *et al* (2015). There is pressing need to determine the factors leading to perishability and limiting the

production and preservation of tomato fruits in Northern part of Nigeria. In this research, the dielectric properties of fresh Roma and Cherry tomato samples were determined, at different temperature and frequency, using LCR meter.

METHODOLOGY

Samples of two varieties of fresh tomatoes, Roma and Cherry were obtained from the farm at three local government areas, Kazaure, Babura and Yankwashi local governments.

The tomato samples were washed and sliced into 4-5 mm thickness, by the use of hand operated mechanical slicer. The sliced tomatoes were used to determine the dielectric properties, with an LCR meter. The slice was dehydrates at a given temperature by using oven machine. Two samples, matured and pre-mature, from each of the varieties were used to prepare four fresh samples. The samples were loaded on a test cell, connected to an LCR meter.

The dielectric properties of tomato, including dielectric constant and dielectric loss factor, were measured using an LCR meter. An LCR meter is a type of electronic test equipment used to measure the Inductance (L), Capacitance (C), and Resistance (R) of an electronic component. So it is just clearly visible that why this device is known as a LCR meter in short for convenience.

$$\epsilon' = \text{Capacitance of sample} / \text{Capacitance of air.}$$
$$\epsilon'' = \epsilon' \times \tan \delta$$

RESULT AND DISCUSSION

The dielectric properties measured the values of dielectric constant, dielectric loss, conductivity and relaxation time as a function of temperature and frequencies are shown in the tables below.

Table 1: Dielectric properties of Roma matured Tomato at 35 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ) (s/m)	Relaxation time(τ) (s)	Resistivity (ρ) (Ω -m)
50khz	35°C	25.66	6.83	1.00×10^{-7}	8.47×10^{-7}	9.981
90khz	35°C	22.27	4.99	8.19×10^{-8}	3.96×10^{-7}	12.216
120khz	35°C	18.55	4.35	6.50×10^{-8}	3.11×10^{-7}	15.387



Table 2: Dielectric properties of Roma matured Tomato at 45 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	45°C	24.79	7.25	1.11×10^{-7}	9.31×10^{-7}	8.974
90khz	45°C	21.72	5.94	7.09×10^{-8}	4.84×10^{-7}	12.218
120khz	45°C	17.58	4.50	8.18×10^{-8}	3.39×10^{-7}	14.100

Table 3: Dielectric properties of Roma matured Tomato at 55 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	55°C	23.92	8.61	8.55×10^{-8}	1.15×10^{-6}	11.695
90khz	55°C	20.89	6.32	1.27×10^{-7}	5.35×10^{-7}	14.804
120khz	55°C	17.26	5.09	5.77×10^{-8}	3.91×10^{-7}	17.327

Table 4: Dielectric properties of Roma pre-mature Tomato at 35 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	35°C	24.25	5.30	1.07×10^{-7}	6.96×10^{-7}	4.912
90khz	35°C	19.29	4.65	1.62×10^{-7}	4.26×10^{-7}	6.161
120khz	35°C	15.12	4.00	1.46×10^{-7}	23.51×10^{-7}	6.866

Table 5: Dielectric properties of Roma pre-mature Tomato at 45 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	45°C	22.90	6.10	1.15×10^{-7}	8.48×10^{-7}	5.398
90khz	45°C	18.30	5.80	1.53×10^{-7}	5.60×10^{-7}	6.537
120khz	45°C	14.12	4.88	1.49×10^{-7}	4.58×10^{-7}	6.720

Table 6: Dielectric properties of Roma pre-mature Tomato at 55 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	55°C	21.63	7.57	1.15×10^{-7}	1.11×10^{-6}	6.516
90khz	55°C	17.48	7.01	1.48×10^{-7}	7.09×10^{-7}	6.735
120khz	55°C	13.44	6.66	1.39×10^{-7}	6.57×10^{-7}	7.220

Table 7: Dielectric properties of Cherry matured tomato at 35 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	35°C	32.41	10.53	1.08×10^{-8}	1.03×10^{-6}	9.242
90khz	35°C	27.37	8.26	5.75×10^{-8}	5.34×10^{-7}	13.804
120khz	35°C	22.30	6.71	6.21×10^{-8}	3.99×10^{-7}	14.897

Table 8: Dielectric properties of Cherry matured tomato at 45 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	45°C	31.68	12.12	9.29×10^{-8}	1.16×10^{-7}	9.222
90khz	45°C	26.22	9.66	5.40×10^{-8}	6.51×10^{-6}	15.866
120khz	45°C	21.54	8.25	6.91×10^{-8}	5.08×10^{-7}	16.714

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Table 9: Dielectric properties of Cherry matured tomato at 55 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	55°C	30.44	14.09	7.23×10^{-8}	1.47×10^{-6}	9.440
90khz	55°C	25.38	10.60	9.08×10^{-8}	7.38×10^{-7}	16.164
120khz	55°C	21.45	9.19	4.80×10^{-8}	5.68×10^{-7}	17.857

Table 10: Dielectric properties of Cherry pre-mature tomato at 35 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ) (s)	Resistivity (ρ)(Ω -m)
50khz	35°C	29.79	6.41	1.11×10^{-7}	6.56×10^{-6}	6.844
90khz	35°C	25.10	5.52	1.64×10^{-7}	3.89×10^{-7}	7.419
120khz	35°C	20.81	4.44	1.39×10^{-7}	2.83×10^{-7}	8.295

Table 11: Dielectric properties of Cherry pre-mature tomato at 45 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ)(s)	Resistivity (ρ)(Ω -m)
50khz	45°C	28.82	7.75	1.48×10^{-7}	8.56×10^{-7}	6.757
90khz	45°C	24.37	7.26	1.63×10^{-7}	5.27×10^{-7}	8.558
120khz	45°C	19.93	6.28	1.14×10^{-7}	4.18×10^{-7}	8.808

Table 12: Dielectric properties of Cherry pre-mature tomato at 55 °C

Frequency (KHz)	Temperature (°C)	Dielectric constant (ϵ')	Dielectric loss (ϵ'')	Conductivity (σ)(s/m)	Relaxation time(τ)(s)	Resistivity (ρ)(Ω -m)
50khz	55°C	28.08	8.91	1.50×10^{-7}	1.01×10^{-6}	6.657
90khz	55°C	23.93	8.33	1.43×10^{-7}	6.15×10^{-6}	8.767
120khz	55°C	19.34	7.39	1.56×10^{-7}	5.07×10^{-7}	9.059

DISCUSSION

Tables 1-12 showed that the dielectric constant at 35 °C is higher than that at 45 °C and 55 °C respectively. The dielectric constant also at frequency of 50 KHz is greater than that at 90 KHz and 120 KHz, this shows that the dielectric constant increases with increasing temperature and increased with increasing frequency. The

lower the temperature and frequency the higher the dielectric constant, the higher the frequency and temperature the lower the dielectric constant. But the dielectric loss it always increases with increasing temperature and decreases with increasing frequency. Moreover the resistivity is increases with increasing frequency for both fresh matured and pre-mature samples.

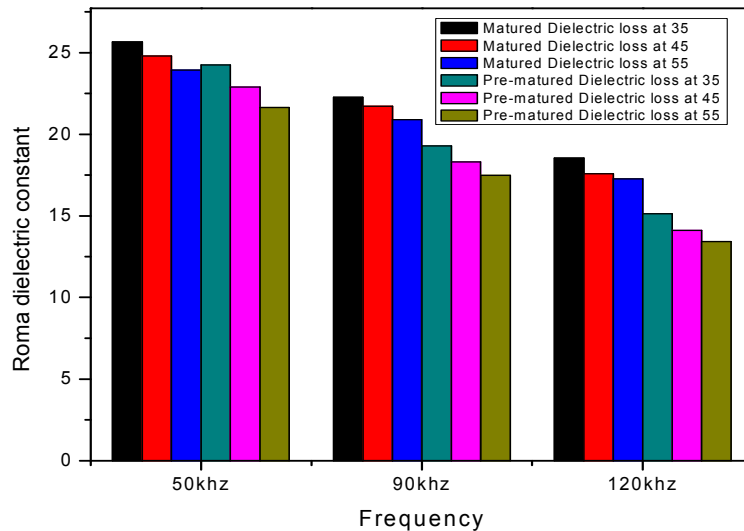


Fig. 1 Roma matured and pre-mature tomato dielectric constant as a function of frequency at 35 °C, 45 °C and 45 °C temperature.

Fig. 1, shows that the dielectric constant (ϵ') for Roma matured, pre mature and dried tomato samples, like cherry and Grape tomatoes, were the Roma dielectric constant decreased by increasing temperature, shows that

the temperature at 35 °C has the high dielectric constant (ϵ') than the others at 45 °C and 55 °C, with the influence of frequency at 50 KHz, 90 KHz and 120 KHz respectively.

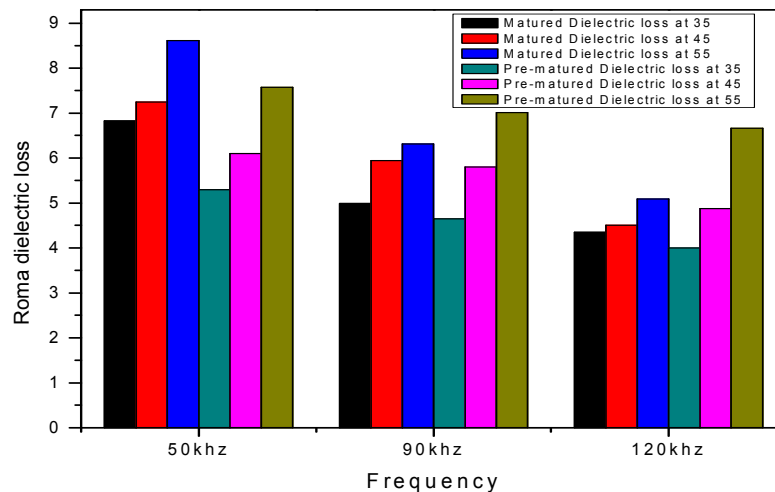


Fig. 2. Roma matured and pre-mature tomato dielectric loss as a function of frequency at 35 °C, 45 °C and 45 °C temperature

Fig. 2, shows the dielectric loss (ϵ'') for Roma matured and pre-mature tomatoes samples, were shows the dielectric loss is increases by increasing temperature, and decreases by increasing the frequency. It shows that the dielectric loss at 55 °C has the high dielectric loss than that of 45 °C and 35 °C, with the influence of frequency at 50 KHz, 90 KHz and 120 KHz respectively. While the high the temperature the high the dielectric loss (ϵ'').

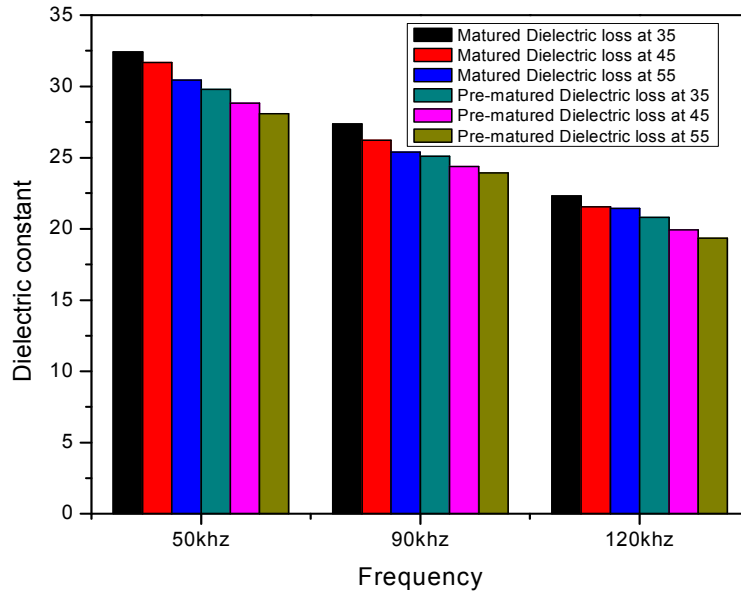


Fig. 3. Cherry matured and pre-mature tomato dielectric constant as a function of frequency at 35 °C, 45 °C and 45 °C temperature

Fig. 3, Shows that the dielectric constant (ϵ') for Cherry matured and pre mature tomato samples were decreased by increasing temperature, while the temperature at 35 °C has

more dielectric constant (ϵ') than at 45 °C and 55 °C, with the influence of frequency at 50 KHz, 90 KHz and 120 KHz respectively.

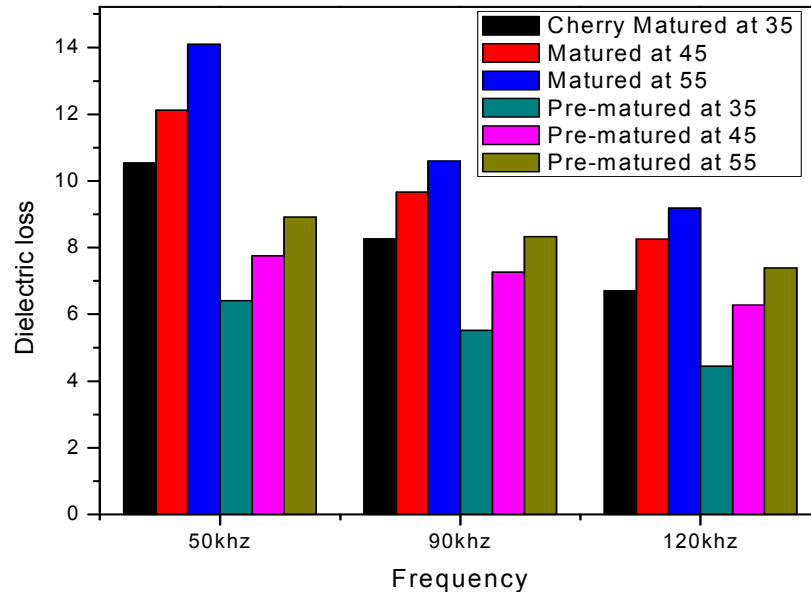


Fig. 4: Cherry matured and pre mature tomatoes dielectric loss as a function of frequency at 35 °C, 45 °C and 55 °C temperature.

Fig. 4, shows that the dielectric loss (ϵ'') for Cherry matured and pre mature tomato samples were increases by increasing temperature, and decreases by increasing the frequency. While the high the temperature the high the dielectric loss (ϵ''). It shows that the dielectric loss at 55 °C has more dielectric loss than that of 45 °C and 35 °C, with the influence of frequency at 50 KHz, 90 KHz and 120 KHz respectively.

CONCLUSIONS

The two tomato varieties, Roma and Cherry, were measured with an LCR meter, at 50 KHz, 90 KHz and 120 KHz frequencies. The measurement was carried out at temperatures of 35 °C, 45 °C and 55 °C. The experimental result show that both dielectric constant and dielectric loss factor decreased with increasing frequency, at 50 KHz, 90 KHz and 120 KHz respectively. As the temperature increases, the dielectric constant was found to decrease, while the dielectric loss was increases, for all the samples at range of 35 °C, 45 °C and 55 °C temperatures. Cherry was

found to have the highest dielectric constant and dielectric loss then Roma sample, the Roma sample has the lowest dielectric constant and dielectric loss. Therefore the moisture content is a critical factor influencing the dielectric properties of tomato samples. Data gathered in this research could be used to reduce the amount of wasted tomato during production and after harvesting as well as packaging process.

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