Effects of Heating on the dielectric properties of egg yolk and egg white of chicken (Gallus Domesticus)

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Abstract. Eggs are livestock products that make the most significant contribution to achieving adequate community nutrition, especially protein. The egg will experience changes when heated. A fundamental change occurs in proteins, namely protein denaturation. The dielectric properties of eggs assessed by measuring capacitance by parallel plate capacitor method. The capacitor plate is 20 x 10 mm² with a distance between 5 mm plates. Parallel plate capacitors are connected in series with the capacitor probe and inductance on the LCR meter GW-instek 816 series and are measured in the frequency range 100-2000 Hz at intervals of 25 Hz. Samples of race chicken eggs are heated with water for 10 minutes, 15 minutes, 20 minutes, and 30 minutes. The results showed that the capacitance and dielectric constant of egg yolk and egg white of chicken (Gallus Domesticus) changes due to heating. This change indicates the presence of protein denaturation and phase changes in fluid in egg white and egg yolk. The dominance of the liquid in the egg white results in changes in a dielectric constant that are greater due to heating compared to changes that occur in the yolk.

1. Introduction
Public attention to the quality of food has been increasing lately. One type of food that consumed is chicken eggs. Heating the chicken eggs are done before consumption. The cooking of chicken eggs will result in reduced nutritional composition in it [1]. Changes in the form contained in chicken eggs will change the chemical, biological, and physical properties of these materials. Food quality measurements have been carried out using various techniques, and In particular, food quality measurements based on the electrical properties of the material have been carried out by different methods [2–7].

Electrical properties of materials include electrical impedance, electrical capacitance, and dielectric constants that are influenced by the composition of the article [7–12]. In principle about conductance and dielectric constant, they are independent (i.e., Ohmic conductivity and permittivity) but in practice, due to dispersive transport and electrode polarization, they are frequently inter-related, especially in composites where this material also has interfacial polarization at the filler or matrix interface. Frequency-dependent conductivity observed when polarization does not follow AC-field, where the dielectric loss occurs. There may be a situation where dielectric loss is negligible at frequencies much lower or much higher than relaxation frequency, but the dielectric constant will be significant due to electric polarization.

Studies of thermal effects on eggs have been carried out by applying measurements of dielectric constants and conductance of eggs at microwave frequencies namely 27 MHz, 40 MHz, 915 MHz, and 1800 MHz. The results show that thermal denaturation in the egg white affects the value of the dielectric constant [13]. This study aims to analyze the thermal effects on egg yolk and egg white-based on
measurements of conductance and dielectric constants at low frequencies in the range between 1 to 2000 Hz.

2. Materials and Methods

The composition of egg whites as in Table 1 [14]. Samples of chicken eggs using fresh eggs from chicken farms, and sorting based on mass (which is about 64 grams). The thermal application of eggs uses 1200 mL of water, which cooked on an electric stove, and the temperature of the water is measured. Egg samples obtained after 10 minutes, 15 minutes, 20 minutes, and 30 minutes of heating, then separated the yolk and egg white. The measured temperature at 0, 10, 15, 20, and 30 minutes is 26.1, 51.4, 68.4, 77.4, 97.2 degrees Celsius, respectively.

Table 1. The Percentage of the composition of a chicken egg

|        | Water | Protein | Fat | Minerals |
|--------|-------|---------|-----|----------|
| white  | 88    | 11      | 0.2 | 0.8      |
| yolk   | 48    | 17.5    | 32.5| 2        |

Figure 1. System Acquisitions Data

Egg yolk and egg white samples placed in a reactor container measuring electrical properties, made of PCB with dimensions of 2 cm x 1 cm x 0.5 cm. Both sides of the reactor container connected by cables prepared for measurement using the 816 series GW-Instek LCR meter, as shown in Figure 1. Analysis of the capacitance and dielectric constant of egg samples in the frequency range of 100 to 2000 Hz. Calibration of the data acquisition system by measuring the reactor container without containing an egg sample, the results are shown in Figure 2 for the capacitance value and the dielectric constant of the empty container.

Figure 2. Capacitance and Dielectric constant of air

3. Results and Discussions

The dielectric nature of biological tissue depends on frequency or dispersive. Significant changes in the dielectric properties in the frequency range, by convention, are called dielectric dispersions. Dielectric spectroscopy is sensitive to dynamic processes which involve the reorientation of dipolar entities or the displacement of charged objects, which can lead to the dispersive behavior of dielectric constants and loss. Dielectric properties used in the assessment of food quality [15].
At room temperature conditions (measured 26.1 degrees Celsius), the value of the egg white capacitance and dielectric constant is smaller than the yolk, as in Figure 3. In this situation, the composition of the liquid or water has a significant contribution to the value of the capacitance or dielectric constant.

![Figure 3. The capacitance and dielectric constant value of the sample at 26.1 degree Celsius.](image)

The dielectric constant and the capacitance of the chicken egg decreases with increasing frequency, as shown in Figure 4 and Figure 5. These characteristic behaviors of the dielectric materials could be described by the polarization and ionic conduction mechanism when an electric field applied in the dielectric material. This situation makes the dielectric is polarized, which oriented by the external field. Total polarization describes the size of the dielectric permittivity.

![Figure 4. The graph of the measurement of dielectric constant value of egg white at various heating temperatures.](image)
The polarization contributes to the shift of the electrical field without any time delay at low frequency. As frequency increases, then the complete polarization of the dielectric decreases as frequency increases. Since the egg is composed of two components, one is a dipolar loss, and the other is an ionic loss. Moisture and ionic conductivity affect the dielectric properties with temperature. If water is in bound form, then dielectric properties increase with the increase in temperature, and if the water is in a free state in the materials, then dielectric properties decrease with increase in temperature.

As a result, the change in dielectric properties with temperature depends on the ratio of bound and free water present in the materials. The variation of dielectric properties of materials with temperature is different for different materials because the constituents and moisture of material vary. The dielectric properties depend on ash present in the elements. At higher temperature, the movement of ions increases; therefore, loss factor increase. As food contains a variety of constituents, the effect of temperature may have a different mechanism for different seeds.

\[ \text{Figure 5. The graph of the analysis of dielectric constant value of egg yolk at various heating temperatures} \]

\[ \text{Figure 6. Graph of the effect of heating temperature on the value of the dielectric constant at a frequency of 100 Hz and 1000 Hz for samples} \]

The thermal effect on an egg influences the dielectric constant value, as shown in Figure 6. The thermal application process applied to egg whites and yolk provides reasonable hygiene control but also causes changes in functional properties. Warming the egg white makes globular proteins vulnerable to changes in structure and conformation. Denaturation in gelation or coagulation depends on the duration and temperature of heating.
4. Conclusion
The results showed that the capacitance and dielectric constant of egg yolk and egg white of chicken (Gallus Domesticus) changes due to heating. This change indicates the presence of protein denaturation and phase changes in fluid in egg white and egg yolk. The dominance of the liquid in the egg white results in changes in a dielectric constant that are greater due to heating compared to changes that occur in the yolk.

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References
[1] Sosa-Morales M E, Valerio-Junco L, López-Malo A and García H S 2010 LWT - Food Sci. Technol. 43 1169–1179.
[2] Marikkar J M N, Lai O M, Ghazali H M and Man Y B C 2001 J. Am. Oil Chem. Soc. 78 1113–1119.
[3] Zhao Y, Chen D, Luo Y, Li H, Deng B, Huang S B, Chiu T -K, Wu, R. et al. 2013 Lab. Chip. 13 2272.
[4] Xu Y, Xie X, Duan Y, Wang L, Cheng Z and Cheng J 2016 Biosens. Bioelectron. 77 824–836.
[5] Mollahosseini M, Daneshzad E, Rahimi M H, Yekaninejad M S, Maghbooli Z and Mirzaei K 2017 Ethiop. J. Health Sci. 27 401.
[6] Zhang D and Liu Q 2016 Biosens. Bioelectron. 75 273–284.
[7] Widodo C S, Sugianto W, Effendi A M and Saroja G 2019 J. Phys. Conf. Ser. 1153 012121.
[8] Widodo C S, Sela H and Santosa D R 2018 The effect of NaCl concentration on the ionic NaCl solutions electrical impedance value using electrochemical impedance spectroscopy methods (AIP Conf. Proc., AIP Publishing LLC) p. 050003.
[9] Widodo C S, Santoso D R and Juswono U P 2016 J. Enviromental Eng. Sustain. Technol. 3 65–69.
[10] Widodo C S and Saroja G 2017 A study of application of two probes at frequency 0.1 to 10 kHz in electrical impedance measurement system for various fats, (Proc. - 2017 Int. Semin. Sensor, Instrumentation, Meas. Metrol. Innov. Adv. Compet. Nation, ISSIMM)
[11] Paszkowski B, Wilczek A, Szyłpowska A, Nakonieczna A and Skierucha W 2014 J. Food Eng. 138.
[12] Jha S N, Narsaiah K, Sharma AD, Singh M, Bansal S and Kumar R, 2010 J. Food Sci. Technol. 47 1–14.
[13] Wang J, Tang J, Wang Y and Swanson B 2009 LWT - Food Sci. Technol. 42 1204–1212.
[14] W. Gisslen 2013 Professional baking (New York: John Wiley & Sons)
[15] Żywica R, Banach J K and Kiełczewska K 2012 J. Food Eng. 111 420–424.