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Investigation of Original Honey Based on Electrical Impedance

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ABSTRACT

Honey comes from nectar extracted by bees and benefits the food industry. However, marketing often involves deception, such as mixing it with sugar. This study aims to distinguish between original honey and honey with adding sugar based on electrical impedance. The study was carried out to measure pure forest honey (*Apis dorsata*) and honey that was added sugar from 10 g to 60 g, where current 30 mA was applied at 100 Hz – 100 kHz. Additionally, some physicochemical characteristics of honey were measured to compare with the electrical impedance. The result shows that pure honey's impedance is lower than adding sugar. The electrical impedance of pure honey increases with the addition of sugar. Investigation of the electrical impedance on quality of honey preferable applied at the frequency from 100 Hz to 1 kHz.

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1. Introduction

Indonesia is an agricultural area with many types of plants growing. Natural forests with various kinds of flowering plants every year have the potential to produce a variety of nectar. Honey is a thick, sweet-tasting liquid bee extract from nectar and plants' sweet components. Bees collect nectar from plant flowers through a combination of enzymes subsequently converted into salivary secretion (Abu Bakar et al., 2017). The main components of honey are 30.3% sugar and 38.3% fructose, which causes honey to taste sweet. The antioxidant content in honey is very abundant (Abd Jalil et al., 2017). The antioxidant properties of honey come from enzymatic substances such as catalase, sugar oxidase, and peroxidase. Enzymatic substances include ascorbic acid, alpha-tocopherol, carotenoids, amino acids, proteins, products of the Maillard reaction, and phenolic acid flavonoids (Saranraj & Sivasakthi, 2018). For instance, Indonesia has a diversity of local honey, such as *Apis cerana*, *Apis dorsata*, and *Tetragonula fuscobalteata* (Lamerkabel et al., 2021). There are some advantages of honey, such as herbal medicine for the prevention of diseases, increasing endurance, and as a cosmetic ingredient (Saranraj & Sivasakthi, 2018), a source of energy, organic acids, vitamins, minerals, flavonoids, and enzymes.

As a natural product with a relatively expensive price, honey has long been a target for counterfeiting (Aljohar et al., 2018). The study of honey's physical and chemical properties is increasingly being applied as a certification process to qualify honey samples. The authenticity of honey is essential from commercial and health aspects. Honey adulteration can occur by adding foreign substances such as molasses, starch solution, sugar, sucrose, water, and sugar or by a change in the physiochemical parameters (Alqarni et al., 2014). Impure honey loses some nutritional and medicinal benefits compared with pure honey, which may vary significantly due to its physicochemical properties. In decades, the research on honey's physical and chemical properties has increased because these parameters are essential for the certification process that determines honey quality (Aljohar et al., 2018; Alqarni et al., 2016; Pazoki et al., 2014; Mohammed et al., 2017). There are analytical methods to authenticate the impureness of honey using front-phase fluorometric spectroscopy, infrared spectroscopy, and nuclear magnetic resonance (Siddiqui et al., 2017). However, the analytical technique is expensive, and hand-carrying is impossible.

In recent times, an impedance spectroscopy method has been used widely in electronic measurement, circuit, sensor characterization, and testing and has also been applied in medicine and biology. This method is an alternative due to the fast and low cost of controlling food quality, fruits, and vegetables (Sruthi et al., 2020). Tests on the quality of honey have been carried out by several studies, including regarding the determination of the physicochemical characteristics of several types of honey using conventional and chemical methods (Prabowo et al., 2020) while concerning the relationship between the origin of flower honey and the impedance (Indriyani et al., 2018). Additionally, some researchers have developed prototypes for measuring parameters related to honey composition, such as sugar concentration, water, and conductivity (Hidayatullah et al., 2017). Consequently, the information and technique are necessary for investigators to determine the purity of honey.

The current work focuses on the effect of adding sugar to honey with the electrical impedance technique in the frequency range 100 Hz – 100 kHz. In addition, several physicochemical properties of honey were measured to compare with impedance as reference data. This research aims to differentiate pure honey and honey with added sugar based on the magnitude of electrical impedance.

2. Methods

2.1. Sampling

The sample of forest honey (*Apis dorsata*) was bought from the local market in Wetar Maluku Barat Daya (MBD) Regency of 460 mL. The sample was prepared for measurement of electrical impedance and physicochemical parameters. The sample was divided into pure honey (p) and honey with additional sugar (s) from 10 g(p+s60) to 60 g (p+s60) with increments of 10 g.

2.2. Measurement of Electrical Impedance

Figure 1 shows an experimental design for electrical impedance measurement. The current of 30 mA, in the frequency range from 100 Hz to 100 kHz, is applied from an electrochemical impedance, and the data is transferred to the PC through a General-Purpose Interface Bus (GPIB) USB. The data was automatically recorded on a PC and plotted in the Kaleida Graph. Furthermore, the correlation between electrical impedance and adding sugar was analyzed using a statistical method.

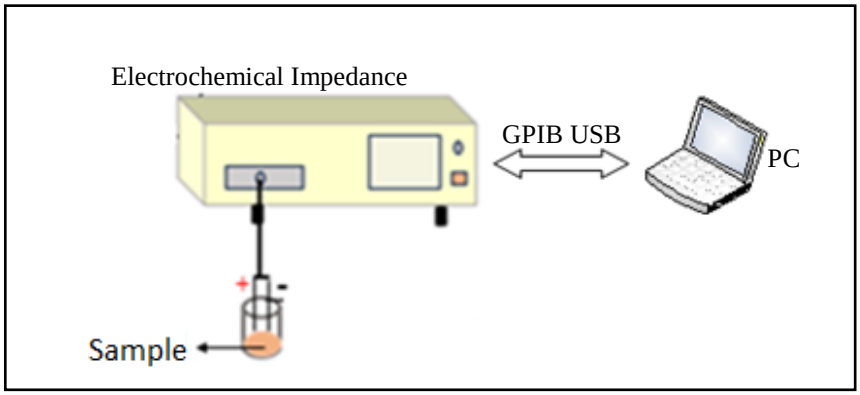


Figure 1. Setup Experimentation for Measuring The Electrical Impedance of Honey

The equivalent parallel circuit is shown in Figure 2, and capacitance was calculated using the equations below.

$$C_p = \frac{B}{\omega} \quad (1)$$

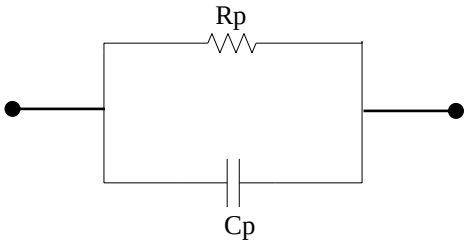


Figure 2. Equivalent Circuit Model of Honey

2.3. Physicochemical analysis

Physicochemical analyses were categorized into primary and secondary data. Conductivity and pH are primary data measured using a CD-4322 and pH tester 20. Seven samples, pure honey (p), p+s10, p+s20, p+s30, p+s40, p+s50, and p+s60 prepared for primary data measurement. The Naberthen and UN110 ovens were used to measure secondary data of water and ash content of pure honey (p), p+s10, and p+s20.

3. Results and Discussion

3.1. Results

Figure 3 shows the electrical impedance measurement that describes the trend changes in impedance between pure forest honey and forest honey with the addition of sugar where the impedance of pure forest honey is the frequency of 100 Hz is 3638 Ω. The electrical impedance of p+s10, p+s20, p+s30, p+s40, p+s50, and p+s60 were 4709 Ω, 6785 Ω, 9414 Ω, 12323 Ω, 15640 Ω, and 18388 Ω, respectively.

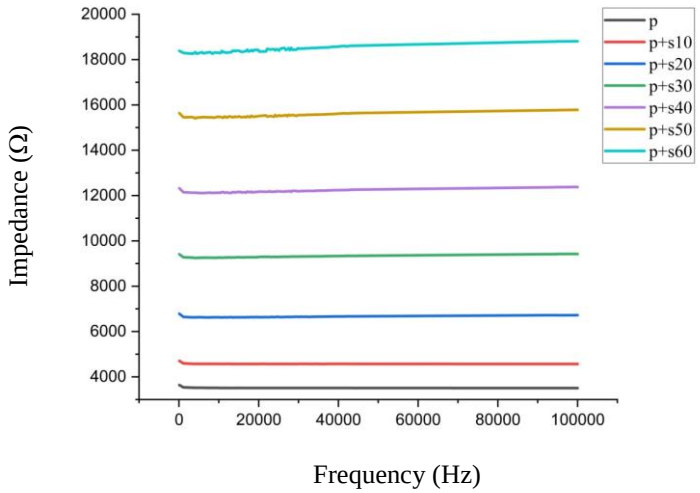


Figure 3. Impedance of Honey Without and With Adding Sugar

Adding sugar to honey increases impedance, as in Figure 3. Electrical impedance as a function of frequencies shows a strong unidirectional relationship between impedance and adding sugar to the honey solution, as shown in Figure 4. The coefficient of determination (R^2) of 100 Hz, 1 kHz, 5 kHz, 10 kHz, 50 kHz, 100 Hz were showed 0.9826, 0.9819, 0.9818, 0.9817, 0.9813, 0.9814, respectively.

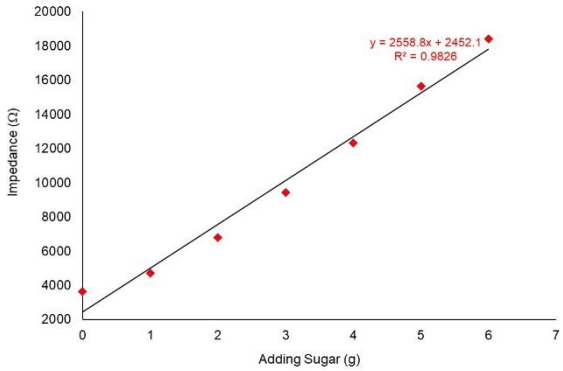


Figure 4. Correlation Between Electrical Impedance and Adding Sugar

On the other hand, the capacitance of pure honey and sugar is reported in Figure 5. The capacitance of pure honey was higher than adding sugar. Capacitance decreased dramatically at frequencies between 100 Hz and 20 kHz, whereas it slightly changed at frequencies over 20 kHz.

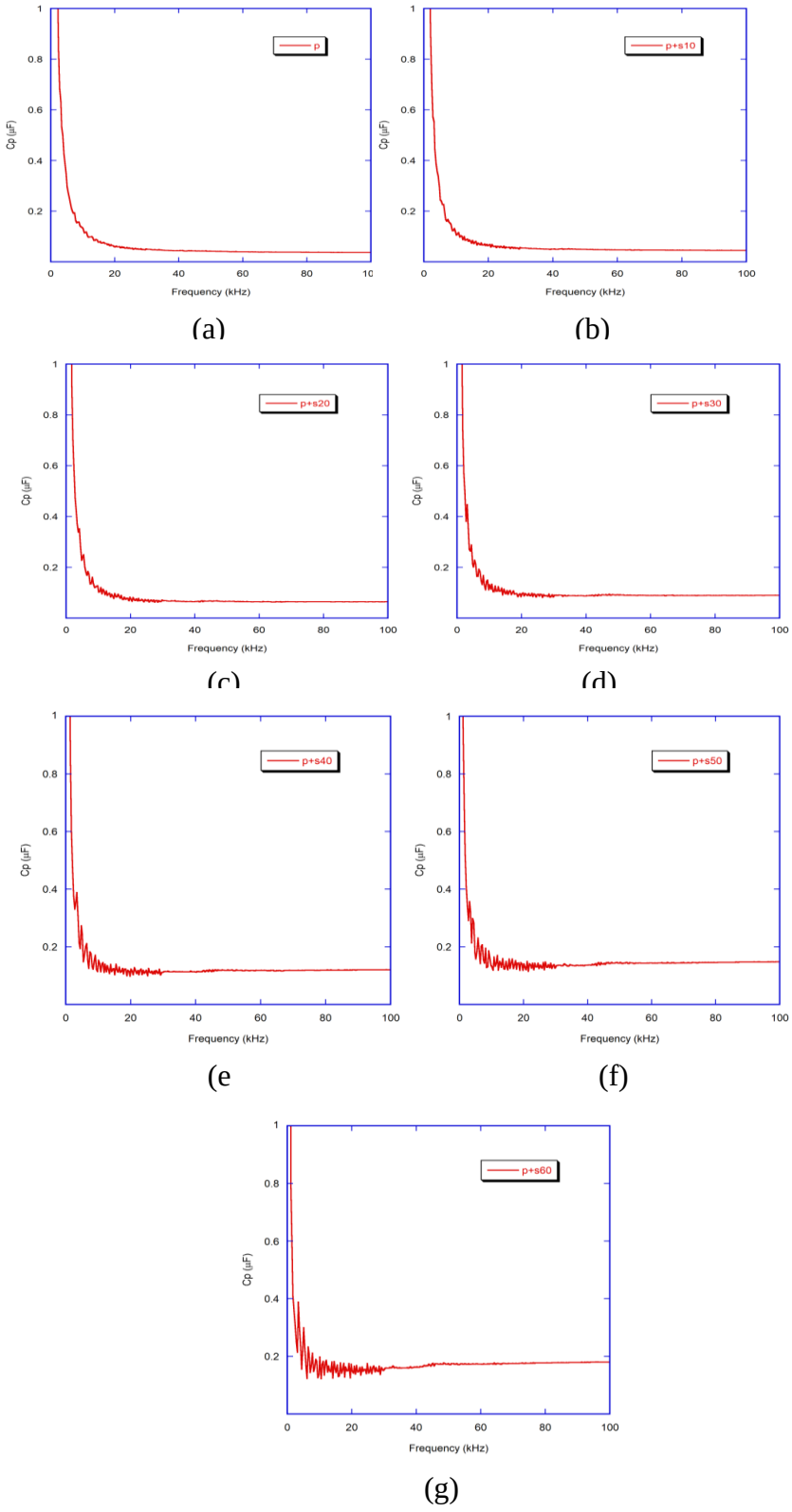
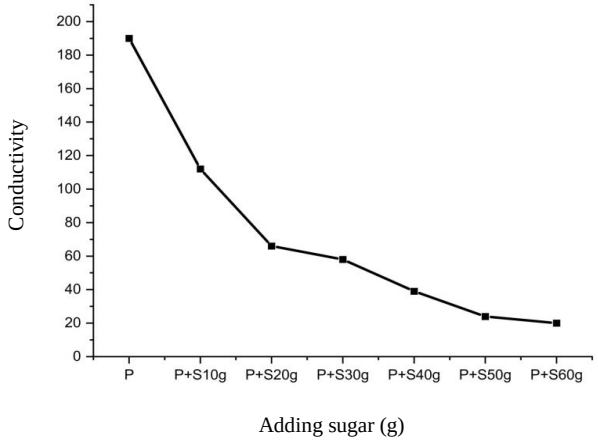
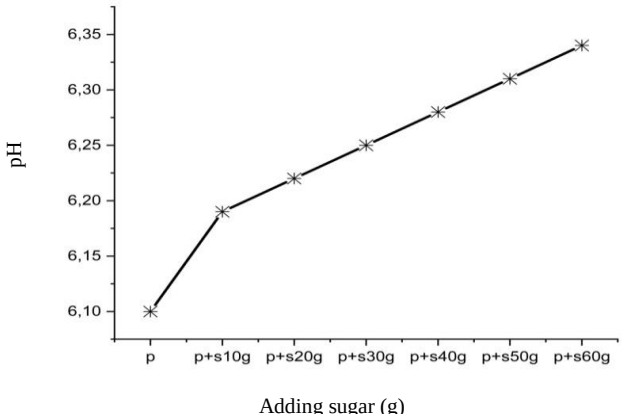


Figure 5. Capacitance of Honey (a) Pure Honey (p), (b) p+s10, (c) p+s20, (d) p+s30, (e) p+s40, (f) p+s50, (g) p+s60

Figure 6 (a) shows that the conductivity (σ) of pure honey decreased with the addition of sugar between a maximum of 190 μS/cm and a minimum of 20 μS/cm. On the contrary, the pH was increased from 6.1 to 6.3 by adding sugar, as shown in Figure 6 (b).



(a)



(b)

Figure 6. (a) Conductivity and (b) pH of Without and With Adding Sugar

Water and ash content present a decrease in the addition of sugar into honey. Water and ash content of pure honey (p), p+s10, and p+s20 were 22.86 % and 0.62 %, 21.61 % and 0.58 %, 19.44% and 0.50 %, respectively.

3.2. Discussion

The impedance of honey increases with each addition of granulated sugar due to the influence of the constituent components. The more sugar added to honey, the more difficult it is for the sugar solution to conduct an electrical charge. Sugar crystals mixed with solvent ions do not have attractive interactions between atoms. The more sugar added to honey, the more excellent the resistance. This causes the amount of current flowing to be smaller. The results show a close relationship between the amount of sugar added to honey and impedance, which is 98.26%, which means that there is a unidirectional relationship between the addition of sugar in honey and impedance. The electrical impedance has a relationship with electrical conductivity. Impedance increased, but conductivity decreased, and vice versa.

Conductivity is the ability of matter to allow electric current from an ingredient with mineral content. Differences in conductivity are often applied to the characterization of the origin of honey botany and the determination of honey quality. The ash content indicates the amount of mineral content in honey. The greater the mineral content of honey, the higher the ash content. Minerals contained in honey include Mg, Ca, Fe, and Na (Siddiqui et al., 2017; Antary et al., 2013; Putri et al., 2017; Rivera-Mondragón et al., 2023; Alqarni et al., 2014). Minerals are ions that can affect electrical conductivity so that they can affect impedance. The increase of ions in honey indicated by ash content will increase the electrical conductivity so that the impedance decreases. The smaller the ash content, the greater the electrical impedance of honey (Scandurra et al., 2013).

Hygroscopic is one of the properties of honey that allows it to absorb water quickly, so that will affect the amount of water in it. In tropical countries, for example, Indonesia shows an increase in the high amount of water in honey in the rainy season (Sjamiah et al., 2018). In addition, the high-water content can make the honey immature. The higher water content in honey shows low quality (Wilczyńska & Ruszkowska et al., 2014), and water aggregation formation increases as the water temperature increases (Talapessy & Elim, 2016). pH is the concentration of ions that describes the acidity and basicity of a solution. Pure honey has a pH ranging from 3.4 to 6.1. When sugar is added to the honey sample, the pH will increase because sugar has a neutral pH of about 7. Total acidity shows the transformation of enzymatic made by bees.

On the other hand, the capacitance of pure honey was large at lower frequencies and then decreased with an increase in the frequency due to interfacial polarization (Talapessy et al., 2020). Interfacial polarization occurs when an accumulation of charge at an interface between two materials or between two regions within a material because of an external field. Capacitance fluctuations in pure honey and granule sugar at frequencies ranging between 200 Hz and 30 kHz that ion interactions may have caused. Adding sugar to the honey solution shows a unidirectional relationship with increased impedance. Based on R^2 in Figure 4, 100 Hz – 1000 Hz is very suitable for testing honey, with the time-consuming measurement being shorter than sweep frequencies 100 Hz – 100 kHz.

4. Conclusion

The results of measuring the characteristics of the electrical impedance of honey without mixture and with added sugar concluded that the impedance of honey decreases as the frequency increases. Testing the treatment of honey with added sugar affects the impedance. The more sugar added to honey, the higher the impedance. The suitable frequency for measuring the purity of honey is 100 Hz – 1 kHz.

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