Study on the effect of sugar canes and saccharin to the value of electrical impedance of apple cider manalagi (*Malus sylvestris mill*)

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**Abstract.** Saccharin additives addition as a substitute for natural sweeteners is done to reduce production costs. This paper will discuss the effect of sweetener on the electric impedance of apple cider. The electrical impedance spectroscopy method was applied to the sample using four electrodes. Electrical impedance measurements made by injecting 100 μA currents in samples within the chamber in the frequency up to 1 MHz. The results showed that the electrical impedance value of apple cider manalagi is 1721.166 Ω to 41.870 Ω. The effect of sugar canes mass composition and saccharin mass added to apple cider can be observed well in low frequency up to 10 kHz. The electric impedance characteristic of the apple cider manalagi increases with the addition of sugar canes mass, whereas the electric impedance value of the apple juice manalagi decreases with the addition of saccharin mass.

1. Introductions
The addition of sweeteners needed in the processing of apple manalagi into apple drink products. The most widely used sweetener is sugar sweetener from sugar canes. But there are times when to reduce the production costs are usually used as artificial sweeteners such as saccharin. Saccharin is a sodium salt of saccharin acid which has a sweetness level of 300 times the regular sugar or sucrose. Biochemical markers in the liver and kidneys can be damaged by high or low doses of saccharin[1]. Falsification of foodstuffs that do not consider nutrition and health are often carried out due to lack of supervision by related parties, such as counterfeiting liquid food. The expensive technology through sophisticated laboratory measurements will get more accurate results [2]. Until now, many electrical impedance spectroscopy methods have been applied to detect the presence of pollutants in food [3]–[7]. This paper discusses the effect of adding sugar canes and saccharin contaminants to apple cider. This research is a continuation of previous research, about electrical impedance measuring device by using various electrode materials, where, the results of prior study indicate that the principle of impedance measurement using LCR meter can distinguish a beef fat, chicken fat and lard, in addition, parallel plate method can measure changes in sugar cane concentration [8], [9]. Device development conducted in this research is the electric impedance measuring device using four electrodes.

2. Experimental Sections

2.1. General
Changes in the physical state of a material, where the material can be equivalent in an electric circuit, can be determined by using an electric impedance spectroscopy method. Materials used in this study is
apple cider manalagi. Apples sorted according to similar colors, shapes, and sizes, cut into pieces and immersed in water at 80°C for 5 minutes, then blend. The apple cider obtained by filtration of apples resulting from mixing of 20-gram apples and precipitation for 30 minutes. The essential ingredients of apple cider are added sweeteners and stirred using a magnetic stirrer for two minutes, then heated to 90 degrees Celsius using an electrical oven for 15 minutes. The apple cider is allowed to stand for 1 hour at room temperature. Addition of sugar canes or sucrose to apple cider respectively 10 g, 15 g, 25 g, and 50 g, and the addition of artificial sugar saccharin with mass 10 mg, 30 mg, 50 mg, and 70 mg.

2.2. Measurement Systems
The principle of impedance measurement with four electrodes was applied to the sample of apple extract as shown in Figure 1. In general, Electric current injection from V to I converter is 100 μA into apple cider sample via two electrodes (A1 and A2), and electric impedance measurement by using two needle electrodes B1 and B2. PICOSCOPE series 5000 with type 5422B supports impedance measurement by recording input potential (Vin) and output potential (Vout), and as a signal controller. The input voltage (Vin) is 1 Volt. Samples of apple cider placed in a container sample made of acrylic, with dimensions in the tube length 2.3 cm and tube diameter 2.7 cm. At the end of the container, there are two gold plate electrodes (A1 and A2) in the form of a 0.8 cm diameter circle with the spacing between the plates is 2 cm. In the middle between the two plates A1 and A2, there are two gold needle electrodes (B1 and B2) with a distance between the needles 0.6 cm. The electrical impedance measured up to 1 MHz. The voltage used to measure the impedance value is the peak to peak voltage of the output voltage (Vout) divided by two. The electrical impedance value is obtained by calculating the potential divided by the injected current.

![Figure 1](image)

**Figure 1** The electrical impedance measurement system using four electrodes.

3. Results and Discussion

3.1. The effect of sugar cane on the electric impedance of apple cider
Apple manalagi is one of the varieties of apples that are commonly grown in Indonesia. The chemical composition of the apple is as shown in Table 1. The structure will affect the nature of electricity. In
Figure 2, the apple cider's electrical impedance value tends to decrease as the frequency increases. The double layer effect between samples of apple cider and impedance measuring electrode appears at low frequencies, where electrical impedance tends to have a higher value.

Table 1 The Chemical Composition of Apples Manalagi per 100 grams of apples [10].

| Composition            | Total  |
|------------------------|--------|
| Sugar (g)              | 8.29   |
| Acidity (g)            | 0.32   |
| Vitamin C (mg)         | 6.6    |
| Reducing sugar (g)     | 6.96   |
| fruit fluid pH         | 4.62   |
| Fructose (g)           | 4.5    |
| Glucose (g)            | 3.72   |
| Sucrose (g)            | 4.54   |
| Sugar/acid (g)         | 42.56  |
| Antioxidant activity (g)| 6.53  |
| Total dissolved solids (Brix) | 17.1 |

Figure 2 The electrical impedance value of the apple cider at the frequency range 1 Hz - 1 MHz at various additions of sugar cane mass.

Sugar canes produced by filtering the content of sucrose in cane, so that sucrose dominates sugar cane. The addition of sucrose raises the electrical impedance value of apple cider. Sucrose is a polar compound, so the addition of sucrose in apple cider will inhibit the movement of the existing ions. The more the amount of sucrose, the more impeded the flow of the current ions so that the impedance value will rise [11]. The result supports the impedance measurements as in Figure 3, where at frequencies up
to 10 kHz the impedance value increases with increasing mass of sucrose. At 1 MHz, impedance measuring devices are unable to discern any changes in the sucrose.

![Figure 3](image.png)

**Figure 3** The electrical impedance of apple cider tends to increase due to the addition of sugar canes at various frequencies.

3.2. The effect of saccharin on the electrical impedance of apple cider

The electrical impedance of apple cider influenced by frequency, where the impedance value decreases with increasing frequency. The result, Fig. 4, shows the same conditions as the results in Fig. 2. Figure 4 shows the characteristic of apple cider impedance with the addition of saccharin. The addition of sweetener saccharin results in decreasing the value of apple cider impedance. This result is in contrast to the addition of sweetener sugar canes (sucrose). Saccharin sweeteners commonly used for food is sodium saccharine type. Sodium saccharin will form ions when dissolved in the liquid, i.e., the formation of Na⁺ ions. The apple cider impedance decreases due to the presence of these ions. The more the addition of saccharin sweetener to the apple cider resulted in a reduction of impedance value, as shown in Figure 5. At frequencies 1 Hz to 0.1 MHz it appears that the impedance decreases with the rise of saccharin mass in apple cider. Whereas at 1 MHz, the designed impedance meter is incapable of distinguishing the presence of saccharine, means the measurement limit using an impedance measuring device using four gold electrodes is below 1 MHz.
Figure 4 The value of the electric impedance of apple cider in the frequency range 1 Hz - 1 MHz at the various addition of saccharin mass

Figure 5 At various frequency sampling, the addition of a saccharin sweetener mass decreases the impedance value.

4. Conclusion
The addition of sweetener will affect the value of the electrical impedance of apple cider. The characteristic value of the impedance of the apple cider increases with the addition of sugar canes mass, whereas the electric impedance value of the apple cider decreases with the addition of saccharin mass. Electrical impedance measurements using four electrodes can distinguish the presence of sweeteners
with an impedance value between 1721.166 Ω to 41,870 Ω. The effect of sugar cane mass and saccharin mass added to apple cider can be observed well in the frequency range of 1 kHz to 10 kHz. The system has not been able to work correctly in the 1 MHz frequency.

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