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Design of Portable Ethanol Testing Device for Halal Verification of Alcoholic Beverages

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ABSTRACT— ***It has designed a portable device for halal verification of alcoholic beverages based on ethanol sensor technology using an electrochemical method. Two electrode electrochemical system has developed using nickel wire (Ni) as the working electrode (active) and platinum metal (Pt) as a counter electrode. The platinum electrode acts as an electrocatalyst that oxidizes ethanol by applying an electric voltage. The output current varies with the concentration of ethanol that decreased as the ethanol concentration increases. This output current is converted into an electric voltage, then was input into the microcontroller. The device output is displayed on the LCD in the percent volume (% volume) of ethanol concentration. From the measurement results note that the device designed can detect ethanol up to a concentration of 0.1% or lower. This device has also been tested and able to detect the presence of ethanol in some foods and beverages.***

Keywords— Electrochemical sensor, ethanol, halal verification, microcontroller, nickel, platinum

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1. INTRODUCTION

For a Muslim, it is imperative to choose foods and drinks that are lawful (halal) for consumption. The existence of a halal guaranty for any food and beverage products, such as halal certification, is very important for muslim consumer. In Indonesia, there are institutions that handle and supervise the halal verification product that is LPPOM MUI (Institute for Food Assessment of Medicines and Cosmetics Majelis Ulama Indonesia). One aspect for halal verification in a food and beverage is the alcohol (include ethanol) content contained in the foods or beverages. Generally, the main component in alcoholic beverages is ethanol [1].

Regulations in Indonesia explain that beverage products from alcoholic fermentation processes (naturally present in fermented beverage products) are allowed to be consumed if the amount is very small and not intoxicating, that is less than 1% [2]. Fatwa MUI No. 11, of 2009, on alcohol it is mentioned that alcohol is a general term for any organic compound having a functional group called a hydroxyl group (-OH) attached to a carbon atom. The general formula of the alcohol compound is R-OH or Ar-OH where R is an alkyl group and Ar is an aryl group.

There have been several analytical methods developed in the context of product monitoring and verification of ethanol content in alcoholic foods and beverages. The science innovations are essential to ensure that the products consumed are safe and of quality, especially for Muslims to protect them from unlawful (haram) products. Several instrumentation methods for detecting ethanol include capillary electrophoresis methods [3], High-performance liquid chromatography [4], gas chromatography-mass spectrometry [5], gas chromatography [6], NMR Spectroscopy [7], and Raman spectrometry [8]. These methods have been widely used for food and beverage analysis but in addition to using expensive equipment, the process also takes a long time and test samples must be taken to the laboratory [9].

One of the most widely developed methods for rapid detection of ethanol is the electrochemical method, especially the amperometric method [9, 10]. The principle of this method is based on the reaction occurring on the electrodes. In the electrochemical method, the voltage source is connected to two electrodes namely nickel and platinum, each acting as the working electrode (active) and the counter electrode, as shown in Fig. 1. Nickel is an electrocatalyst for alcohol, where the reaction that occurs between nickel and alcohol will cause a change of current so that the environmental changes can be detected by observing the current. The platinum electrode serves to drain the current between the working electrode and the counter electrode so that the current can be measured [9].

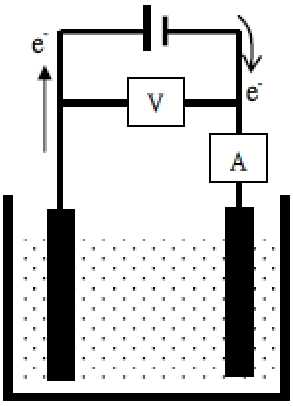

Figure 1: Electrochemical circuit of ethanol measurements

The reaction between the nickel and the alcohol will release the electrons to be read as the current changes flowing in the outer circuit. The result of the analysis using this method can be known from cyclic voltammogram. The principle of the cyclic voltammogram is that the measurement is carried out by applying a potential to the electrochemical cell and the current response resulting from the redox reaction process is measured. The current response is measured at a predetermined potential, then the current is plotted as a potential function. The specific current will be generated from the scanning process [11].

2. EXPERIMENTALS

Equipment for detecting ethanol designed consists of several components, including electrochemical sensor, microcontroller and operational amplifiers (Op-Amp).

2.1 Electrochemical sensor

The sensor used to design ethanol device is an electrochemical sensor. The sensor consists of two electrodes, the nickel wire as the working electrode (active) and the platinum wire as the counter electrode, without using reference electrode. The working principle of this sensor is the electrocatalytic reaction on the working electrode (nickel) with an electric power supply. Nickel is an ethanol electrocatalyst, wherein the reaction that occurs between nickel and ethanol will cause a change of current so that it can detect the presence of ethanol in the solution by observing the current.

The reaction occurring in the nickel electrode can be expressed as follows [4]:

$$NiOOH+C_2H_5OH \rightarrow intermediate\text{-}1+Ni(OH)_2 \quad (1)$$

$$NiOOH+intermediate\text{-}1 \rightarrow CH_3CHO+Ni(OH)_2 \quad (2)$$

$$NiOOH+CH_3CHO \rightarrow intermediate\text{-}2+Ni(OH)_2 \quad (3)$$

$$NiOOH+intermediate\text{-}2 \rightarrow CH_3COOH+Ni(OH)_2 \quad (4)$$

where electrons are generated in reactions 1 and 3. The greater the concentration of ethanol, the smaller the current flows, the smaller the concentration the greater the voltage produced because the voltage and current are directly proportional, based on the relationship V=IR (Ohm's Law). The time required to read changes in current and voltage until stable is 10 seconds. Thus the sensor output is determined by the ethanol content in the solution. By utilizing this electrochemical sensor, much of the information is gained in terms of both qualitative and quantitative analysis. This quantitative analysis will be useful to know the value of ethanol concentration in solution.

2.2 The Arduino Nano ATmega328

The Arduino Nano is one of microcontroller based breadboard that is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). The Arduino Nano was created with ATmega328 microcontroller base (for Arduino Nano version 3.x) or ATmega 168 (for Arduino version 2.x). Arduino Nano more or less has the same function with Arduino. Arduino Nano can be activated via a Mini-B USB connection, or through an external power supply with an unregulated voltage between 6-20 Volts connected via pin 30 or VIN pin, or via an external power supply with a 5-volt regulated voltage via pin 27 or 5V pin. A power supply will be automatically selected from a higher voltage source. The FT232L FT232L chip on the Arduino Nano will be active when powered via USB when the Arduino Nano is powered from outside (Non-USB) the FTDI Chip is off and the 3.3V pin is unavailable, while the TX and RX LEDs Blinks when digital pins 0 and 1 are in HIGH position.

2.3 Operational-Amplifier (Op-Amp)

Operational-Amplifier (Op-Amp) is a high-powered amplifier integrated with an IC chip that has two inverting and non-inverting inputs with an output terminal, in which feedback circuits can be added to control the overall response characteristics of the operational-amplifier (Op-Amp). Basically, operational-amplifier (Op-Amp) is a differential amplifier that has 2 inputs and 1 output. This operational-amplifier is used to form linear functions that are various or can also be used for nonlinear operations and are often referred to as basic linear integrated circuits. The operational amplifier (Op-Amp) is an analog electronic component that acts as a multi-purpose amplifier in the form of an IC and has symbols.

In Arduino, inputs are read in the form of ADC voltage, so it takes the conversion of data obtained from current into voltage. Trans-impedance circuit is used to convert current into a voltage with Op-Amp used as an inverter (Figure 2). This is so readable on the Arduino input in the form of Analog to Digital Converter (ADC) voltage. The inverter is built using Op-Amp and resistance with 560kΩ value, the resistance used must be small because the desired output voltage is less than 5V.

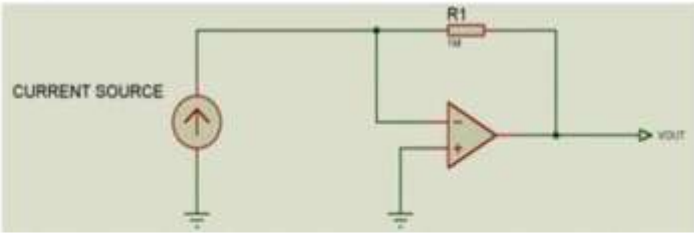

Figure 2: Trans-impedance circuit

2.4 Construction of device

The output voltage data from the inverter is processed by Arduino Nano ATmega328 and converted into bits, the circuit shown in Figure 3. Then a graph of the bits of the ethanol concentration in percent is obtained so that the linear equation (y = ax + b), with y, is the bit and x is the concentration. The output to be displayed is the digit numbers of ethanol concentration contained in the sample. The output of the Arduino will be displayed on the liquid-crystal display (LCD). The LCD used is LCD Nokia 5110. Figure 4 shows a circuit of components on the protoboard before being made into a prototype.

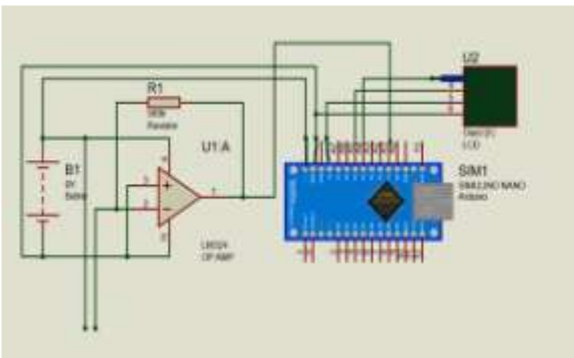

Figure 3: Circuit of ethanol measuring device

3. RESULTS AND DISCUSSION

3.1 Prototype of device

A portable ethanol testing device prototype has been successfully manufactured, as shown in Figure 4. The box-shaped case of PVC material is made using a 3-D printer. LCD display is placed on the front of the device to display digit number of ethanol concentration measurement results. On the side of the device, there is an on-off switch to turn the tool on and off. While at the front of the tool there is a button to start the measurement, each taking of data takes 10 seconds. The sensor electrodes are mounted on the bottom of the device with a homemade cuvette as the container for the sample solution to be measured. The distance between the nickel (Ni) and platinum (Pt) electrodes is 0.3 cm with each length being 2 cm, while the length of the part of electrodes immersed in the solution is 0.8 cm. The principle of measuring the concentration of ethanol is to dip the two electrodes into the sample solution in a prepared cuvette. The instrument reading is set in about 10 seconds to reach the stable state of the reaction at the electrode in order for a more precise reading [4].

Figure 4: Front and opened view of the ethanol testing device

3.2 Response characteristice of the sensor

Testing of the device response that has been designed with ethanol was carried out by using ethanol test solution with varying concentrations are 0%v, 0.1%v, 0.2%v, 0.3%v, 0.4%v, 0.5%v, 1%v, 2%v, 3%, 4%v, 4.5%v, and 5%v, respectively. The device can distinguish precisely these concentrations as shown on the LCD in the voltage (volt) form. Based on the data obtained a plot made between the voltage (volt) and ethanol concentration. The curve of the relationship of the output voltage of the sensor to the ethanol concentration is shown in Fig. 5, indicating that the output voltage decreases with respect to the ethanol concentration as expected. This decrease in voltage due to electron released from the electrocatalytic reaction at the nickel electrode decreases with the increase of ethanol concentration.

On the curve appears two response regions of the sensor, for a low and high concentration of ethanol, that are range from 0.1% - 0.5%v and range from 0.8% - 5%v. The device have different responses in the both ranges as shown at curve characterstics of the different ranges. The range from 0.1% - 0.5%v has a curve steeper than the range of 0.8% - 5%v indicating that the designed device is more sensitive in the low concentration range (0.1% - 0.5%v). By linearizing the two plot curve regions we can determine the sensitivity of sensor in the different regions based on the slopes of the curves. Based on the linear equation of the curves, it is found that the the sensitivity of the sensor are 1,02 V/%C and 0,046 V/%v, respectively for small and high concentration regions. This means that in the low concentration region (0.5% - 0.5%v) every 1% increase in ethanol concentration will produce a voltage output change of 1.02 volts, while in the high concentration region (0.8% - 5%v) every 1%v increase in the ethanol concentration will produce a voltage output change of 0.046 volts. Based on the data we found that the sensor have more sensitive in the low concentration of ethanol so that it can be used to verify the halal food and beverages. It is also known that the correlation coefficient (R^2) of the linear curves respectively are 0.929 and 0.919 for low and high concentration regions of ethanol. Thus it is clearly confirmed that the designed sensor is better and suitable verify the ethanol in low concentration range.

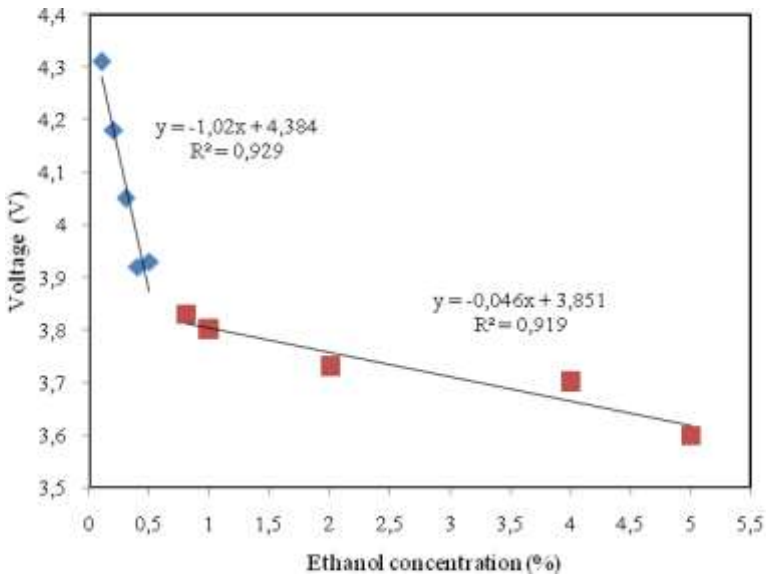

Figure 5: Relationship between voltage output of sensor vs. ethanol concentration

3.3 Device testing in beverages

To ensure that sensors can be used to verify ethanol for a few beverages, tests have been conducted on several commercial beverages. Device testing has been performed on several beverages that are thought to contain alcohol (ethanol). The list of beverages tested and the results of the measurements are summarized in Table 1, testing was performed on four beverages samples with brands as listed in Table 1. The table shows the alcohol content listed on the packaging label and the measurement results using the designed device. Based on the data obtained, it can be determined the difference of measurement results using the designed device with the value listed on the packaging label and determine the error. The test results data show that the concentration value measured by the designed device does not much differ from that listed on the packaging label of the tested beverages. Of the four beverage samples tested, two samples yielded an error of about 3% and other two samples produce errors over 10%, this is a significant measurement error. In this test there is no repeat measurement, so the measurement error is significant. It is therefore necessary to have repeated measurements and further calibrations on the designed device. However, this result shows that the designed device has been able to verify alcohol in the beverage.

Tabel 1: Test results for several alcoholic beverages

No.	Name of samples	Concentration on Package Label (%)	Testing results (%)	Difference (%)	Error (%)
1	Bintang 'Radler'	2	1,94	0,06	3%
2	Smirnoff 'Midnight 100'	4,7	4,15	0,55	11,70%
3	San Miguel 'Dark Lager'	4,86	4,72	0,14	2,80%
4	San Miguel 'Pale Pilsen'	4,9	5,44	0,54	11%

4. CONCLUSION

It has successfully designed a portable ethanol testing device to verify halal of alcoholic food and beverages based on microcontroller-based electrochemical method. The test results show that the device can detect linearly the ethanol content in testing ethanol. The device is more sensitive to the low concentration range (0.1 – 0.5%v) than to the high concentration range (0.8 – 5% v) of the ethanol. Sensitivity at low concentration is 1.02 V/%C, while at high concentration is 0,046 V/%C. This device also can detect the ethanol content in a few alcoholic beverages with still big error from 3 – 11%, however the device can be used for halal verification of alcoholic beverages but with any calibration.

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