Capacitive sensors for determination of the quality of cooking oil

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ABSTRACT

Cooking oil suffers deterioration during the frying process, which may cause health hazard. The frying process increases the concentration of polar components contained in the oil. This concentration can be evaluated by means of gas chromatography. As this concentration changes the dielectric constant, it is correlated to changes in the dielectric constant of the oil. In this work, measurements of the variation of the dielectric constant with frying time are presented. Chromatographic analyses of the oil were also carried out. It is proposed an electronic circuit to measure the sensor capacitance, using the Lock-in amplifier.

Keywords: Cooking oil, dielectric constant, chromatography

1. INTRODUCTION

Frying food in cooking oil for prolonged time can alter its sensorial and nutritional quality, due to chemical reactions. New products are formed, such as free fat acids and saturated fats containing the bad cholesterol, LDL. This oil deterioration is hazardous to the human health. Thus, it is necessary to determine whether the oil is proper for consumption [1].

There are accurate techniques for evaluation of oil quality, such as: gas chromatography and nuclear magnetic resonance [2]. However, such techniques are expensive, and require highly qualified staff to handle the equipments. Hence it is desired an instrument that does not demand a specialized technician and portable. Such equipment could be used to select samples for more accurate chemical analysis.

As the oil is heated continuously at high temperatures, the amount of polar components in the oil increases [1], which should increase its dielectric constant. The determination of the percentage of polar components can be measured by means of gas chromatography. Hence, a correlation can be made between oil dielectric constant and the concentration of polar components. Planar capacitive sensors can be employed to detect variations in the dielectric constant of the oil [3].

This work is divided in four parts, this introduction is the first. Next, the methodology is presented. After that, the analyses is presented, and finally the conclusions.

2. METHODOLOGY

Two samples of refined soy oil of the SADIA brand were examined. The preparation of the samples is described in reference [3]. For the purpose of this work, the oil was fried without any food in it. To carry out the measurements, samples were taken after a determined period of time for chromatographic analysis and for the measurement of the dielectric constant.

2.1 Sensor and Instrumentation

The sensor used in the capacitance measurements was a cylindrical capacitor. The capacitance was measured with the impedance analyzer SR720 LCR Meter. The impedance measurements were performed at the frequency of *10 kHz* and voltage of *1V*. A calibration is done to correct the measurement with respect to the parasitic capacitances. After that, the capacitor is filled with oil, and its capacitance is measured. The measured capacitance is related to the theoretical and parasitic capacitance by the expression shown in Equation (1).

$$C_m = \varepsilon_r * C_{th} + C_p \tag{1}$$

Thus, the dielectric constant of the oil is calculated by:

$$\varepsilon_r = (C_m - C_p) / C_{th} \tag{2}$$

3. ANALYSIS

The dielectric constant is measured as a function of the frying time. For the two oil samples analyzed, the graphics in figure 1 were obtained.

From the plots, it is observed a clear linear variation of the dielectric constant with the frying time. A chromatographic analysis to determine the quantity of polar parts in the oil was performed with the first oil sample; the result is shown in Fig. 2
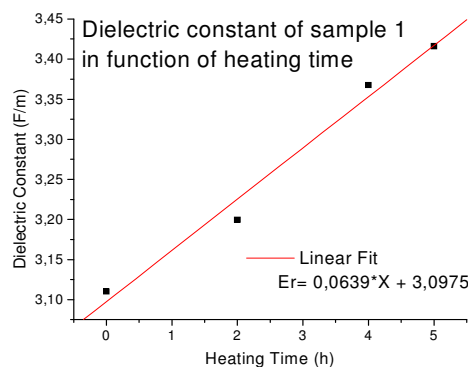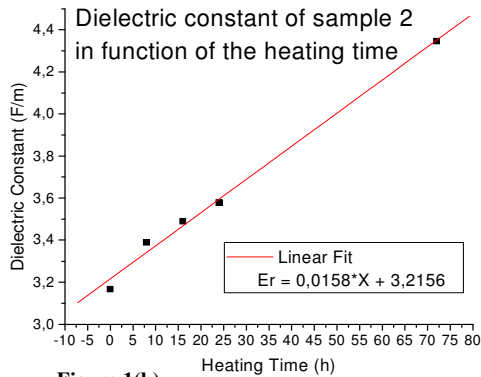

Figure 1(a)

Figure 1(b)

Figure 1. Variation of the dielectric constant of the oil in function of the heating time for: (a) sample 1 (b) sample 2.
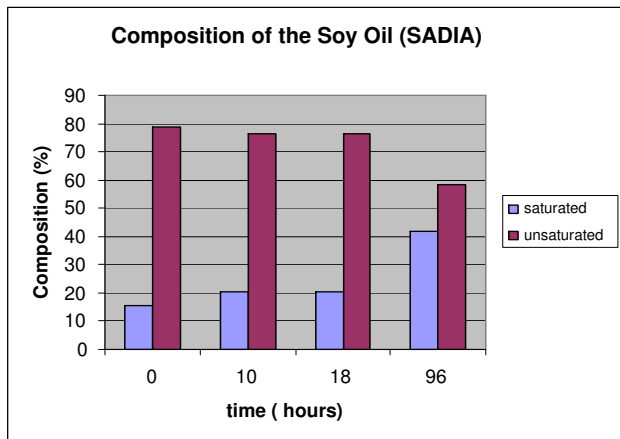

Figure 2. Concentration of polar parts contained in the first sample.

The threshold for excessive frying time is when the concentration of polar components is over *24%*, whereas the maximum limit is *27%* [2]. From the histogram, it can be observed that the oil with *96 h* of continuous frying already has a concentration of over *40%* of polar parts, hence it is unsuitable for human consumption.

The resolution is about *0.05pF* per hour. This is the resolution the circuit must achieve.

3.1 Lock-in Amplifier
The lock-in amplifier can be used to retrieve low magnitude signals hidden in the presence of noise. It can also be used to make high resolution measurements of clean signals, since it isable to detect very small AC signals. It uses a phase sensitive detector (PSD) to select the component of the signal at a specific reference frequency and phase. The lock-in amplifier can be used for the measurement of small impedance changes. The output voltage is a DC voltage proportional to the AC signal under investigation. Therefore, it is possible to get a DC signal proportional to the sensor capacitance. It is proposed that an integrated lock-in amplifier combined with a planar capacitor can be used for the measurement of the dielectric constant of cooking oil. In Fig. 3, there is a schematic diagram of a lock-in amplifier simulated in SPICE.
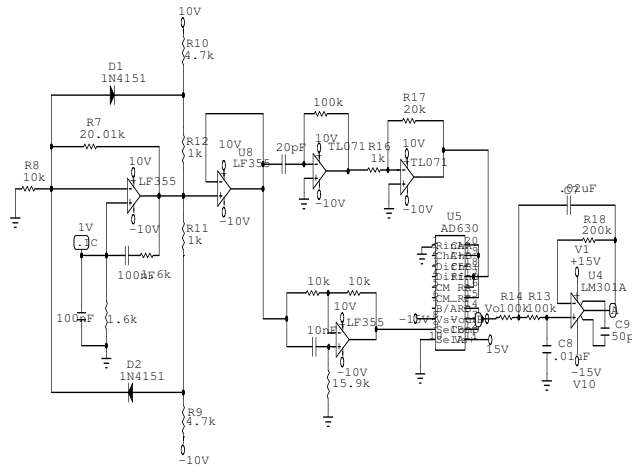

Figure 3. Schematic diagram of the Lock-in amplifier.

4. CONCLUSIONS
It has been observed that the dielectric constant change varies linearly with the frying time. It has also been shown that the dielectric constant change is correlated to the concentration of polar substance, as expected. Thus, by measuring the capacitance, one should be able to determine whether the oil is improper for cooking. This measurement can be accomplished by using the lock-in amplifier concept. The output signal will be a DC voltage proportional to the dielectric constant of the cooking oil.

4. ACKNOWLEDGMENTS

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