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# Adulteration detection in olive oil using dielectric technique and data mining

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ABSTRACT

Olive oil is one of the most important agricultural crops due to its digestive properties and economic status. However, olive oil production is a costly process which causes an expensive price of the final product. The most jobbery ways during olive oil production consist of mixing other oils such as maize, sunflower and soya oil into the olive oil. So, the aim of this study was to develop a dielectric-based system to detect adulteration in olive oil using cylindrical capacitive sensor. For categorizing of fake olive oil by using frequency specification, Linear Discriminant Analysis (LDA) was developed. A set of 15 samples of olive oil, sunflower oil and canola oil which mixed with different ratio of adulteration, were used for calibration and evaluation of developed system. For each sample, 25 iterations were performed. Regarding results, the highest error rate was for a sample containing 60% olive oil-40% canola oil. In general, 7 iterations failed to be properly recognized. Regarding to accuracy indexes, specificity and sensitivity, the system had the minimum error for a mixed sample (60% olive oil-40% canola oil), specificity and sensitivity were obtained as 98% and 100%, respectively and accuracy was obtained as 72%, which was the weakest value. Finally, regarding mean value table for all sample, accuracy reached to 97%. Results showed the developed technique has a good capability of detecting impurities in olive oil. It is concluded from obtained results that the developed system revealed an acceptable adulterated detection in oil production.



## 1. Introduction

Olive oil, which is obtained from olive fruit, could be categorized into raw oil and mixture of raw and refined oil. Based on FAO report, the largest producers of olive oil in the world are Spain, Italy and Greece, respectively. Iran, with 40,000 tons annual production in 2014 holds 11th rank in the world. In 2013, olive cultivation in Iran was 103,000 ha, which indicates that this crop has a considerable importance in Iran. Production of olive oil is very costly that results an expensive price of final product [1]. Fake edible olive oil mostly produced from mixing olive oil with other cheap and low-quality oils. The most fraudulent method used for that purpose is mixing virgin olive oil with soybean, sunflower and canola oil [2]. Adulteration detection, is not easily possible and requires precise, time consuming and expensive methods. Several analytical techniques have been developed for detection and quantification adulteration in olive oil such as mass spectrometry using new type of ion source, direct analysis in real time [3], nuclear magnetic resonance (NMR) spectroscopy [4], infrared spectroscopy [5, 6], Raman spectroscopy [7], fluorescence [8], gas chromatography [9], high performance liquid chromatography [10] and differential scanning calorimetry [11]. Regarding that, developing a method capable of high accuracy and low processing time, would be essential. Therefore, a non-destructive technique such as dielectric spectroscopy due to its repeatability and quick response could be used in olive oil adulteration detection. By dielectric technique, different properties of agricultural materials can be studied and predicted. In this field, many researchers studied different agrifood products and investigated the correlation between dielectric properties and various attributes of materials (Guo et al. [12]; Sacilik and Colak [13]; Nelson et al. [14]).

For instance, Grossi et al. [15] used impedance measurements in the frequency range 20 Hz to 10 KHz for automatic ice cream characterization. Kumar et al. [16] investigated the interrelationship between viscosity and electrical properties for edible oils. They investigated the correlation between viscosity with dielectric loss tangent and electrical conductivity. Yang et al. [17] used dielectric technique in microwave range for moisture content prediction of milk powder. This research aimed to develop a system based on dielectric spectroscopy to identify adulteration in virgin olive oil. To study feasibility of the system, virgin olive oil was adulterated by canola and sunflower oils. In the structure of the proposed system, a simple technique of dielectric measurement was used that solved the mentioned problems such as low processing time and high accuracy.

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## 2. Materials and methods

### 2.1. Sample preparation

At the first step, olive oil samples adulterated with 5, 10, 20, 30, 40 and 50% of sunflower oil were prepared. The same method was repeated for olive oil samples adulterated with canola oil. Also, 3 samples of virgin olive oil, sunflower oil and canola oil were prepared. Therefore, 15 classes of virgin and adulterated specimens were used to develop the system.

### 2.2. System structure

In this research, the designed electronic system by Soltani et al. [18] was used to detect adulteration of olive oil. The device consists of an ATMEGA 16 microcontroller, DC circuit, parallel plate capacitive sensor, signal generator, serial transmitter and receiver port and LCD display. They used a rectangular parallel plate capacitive sensor for egg freshness detection. But in this research, a cylindrical capacitive sensor with capacity of 100 $cm^3$ was fabricated for olive oil. A copper sheet with 0.5 mm thickness and 50 mm height was used as peripheral electrode, a rod with diameter of 6 mm was used as central electrode and spacing between the plates was assumed as 22 mm (Fig. 1). To eliminate electrical conduction, a polyethylene insulator with thickness of 1 mm was covered around central electrode. In the structure of the system, a MAX038 electronic chip was used for producing a sinusoidal signal. Output frequency was controlled by a digital resistor and a variable capacitor and tuned between 40 KHz up to 20 MHz. To measure dielectric related voltage, an AD8302 chip was used. The chip was used for phase difference and attenuation coefficient measurements. To analyze the obtained data, it was necessary that the system should export the dielectric properties to a computer. Therefore, a serial connection between the electoral system and MATLAB®2012, was established. Fig. 2 shows the schematic diagram of the developed system.

### 2.3. Experimental procedure

The experiment was performed in ambient temperature of 25 ± 0.5 °C. The sine wave was set in the range of 40 KHz to 20 MHz to feed into the sensor. It is worth mentioning that a total of 192 waves in the range of 40 KHz to 20 MHz were produced and the related obtained data was stored in the personal computer, which containing 192 voltages correlated to dielectric constant and 192 voltages correlated to dissipation factor of sample. For each sample, 25 iterations were performed. So, a total of 9600 data was acquired for a specimen and 144,000 data for all of the specimens. The obtained data was analyzed in MATLAB®2012 software using Principle Component Analysis (PCA) and Linear Discriminant Analysis (LDA). Finally, olive adulteration was detected by dielectric-based data [18].

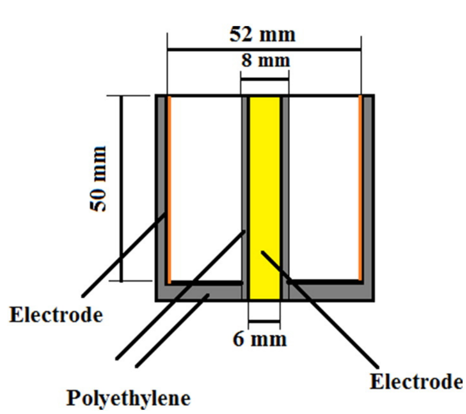


**Fig. 1.** Designed cylindrical dielectric sensor for olive adulteration detection.

### 2.4. PCA

In order to increase performance of the system, choosing useful properties and elimination of irrelevant data was essential. PCA is a way for finding right properties among data set. PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. PCA is a mathematical algorithm that reduces the dimensionality of the data while retaining most of the variation in the data set. It accomplishes this reduction by identifying principal components, along which the variation in the data is maximal. By using a few components, each sample can be represented by relatively few numbers instead of by values for thousands of variables. Samples can then be plotted, making it possible to visually assess similarities and differences between samples and determine whether samples can be grouped. The method can be used for classification as well as for description and interpretation [19–20].

### 2.5. LDA

LDA is a generalization of Fisher's linear discriminant, a method used in statistics, pattern recognition and machine learning to find a linear combination of features that characterizes or separates two or more classes of objects or events. The resulting combination may be used as a linear classifier, or, more commonly, for dimensionality reduction before later classification LDA is one of the most used classification procedure. The method maximizes the variance between categories and minimizes the variance within categories. It merely looks for a sensible rule to discriminate between them by forming linear functions of the data maximizing the ratio of the between-set sum of squares to the within-set sum of squares [21].

### 2.6. Evaluation of the system

In this section, to evaluate performance of the developed system, the procedure consisted of 3 statistical indexes which were used for classification problems named as sensitivity (Eq. (1)), specificity (Eq. (2)) and accuracy (Eq. (3)) presented at the following:

$$S_e = \frac{TP}{TP + FN} \tag{1}$$

$$S_p = \frac{TN}{TN + FP} \tag{2}$$

$$A_C = \frac{TP + TN}{TP + TN + FP + FN} \tag{3}$$

where $TP$, $TN$, $FP$, and $FN$ are the numbers of true positives (correctly identified), true negatives (incorrectly identified), false positives (correctly rejected), and false negatives (incorrectly rejected), respectively and $S_e$, $S_p$ and $A_C$ are sensitivity, specificity and accuracy, respectively.

## 3. Results and discussion

### 3.1. Frequency attributes extraction

Results of acquired data over frequencies from olive oil were prepared to analyze. As mentioned previously, there were 15 samples consisted of olive oil mixture with various ration of other oil products, sunflower and canola. Samples were put into the sensor, individually. Figs. 3 and 4 show a typical acquired data for phase shift related voltage and gain related voltage in mV.