Study of electrical resistance on apples

Jafar MASSAH1, Fatemeh HAJIHEYDARI2

1University of Tehran, College of Abouraihan, Department of Agrotechnology, Tehran, Iran, (e-mail jmassah@ut.ac.ir)
2Urmia University, Agricultural Faculty, Department of Agricultural Machinery, Urmia, Iran

Abstract

Non destructive physical tests are recent trends for quality evaluation of fruits. Information on post harvest variation in electrical resistance and moisture content needs to develop new instruments for this purpose. Electrical resistance and weight of apple stored for 50 days at 22±2 °C. Temperature was measured using LCR Meter and precision electronic balance, respectively. In this experiment, special plate electrodes were developed and used. Constant forces were applied to apple sets located between two plate electrodes. The relationship between the electrical resistance and the weight loss, during the storage period, was also investigated. The results indicated that, the electrical resistance decreases by third degree equation and the weight of apple decreases linearly with increase in storage period.

Key words: apple, electrical resistance, electrical properties, storage, plate electrode

Introduction

The developments of science, technology, and especially of information technology, have made many non-destructive methods available for analysis of materials, which can also be applied to fruits. Fruit industries need non-destructive techniques for on-line sorting and certifying high quality fruits. Numerous studies have been performed to devise accurate food quality measuring techniques. Electrical resistance measurement is a relatively new method applied to food quality assessment.

Electrical methods can detect quality factors and are sensitive to variations in the concentration and state of water. Therefore, it can be associated with maturity, damage, overripe condition, decay or other quality factors (Puchalski, 1994).

There is an increasing need for methods to sort agricultural products according to various standards of quality. The techniques and apparatus used by different authors vary considerably. However, the techniques for solid samples are often costly, sophisticated and bigger in size, thus undesirable to be used by researchers (Jha and Matsuoka, 2000). Development of a new instrument requires a lot of information on engineering properties and their relationships (Jha, 1999). The analytical relationships between electrical resistance properties and quality criteria have not yet been fully developed. Thus, further exploration is needed to acquire more data on electrical resistance, characteristics of fruits, and also employing new approaches for determination of their quality. Electrical properties of fruits are considered as accepted indicators for detecting fruit quality. For example; electrical resistance was used to determine the extent of tissue damage that occurred as a result of bruising of apple fruit (Puchalski, 1994; Jackson et al., 2000; Puchalski and Brusewitz, 2000).

Rotz and Mohsenin (1978) measured electrical resistance of bruised and unbruised tissues in apples. They used two needles inserted into the apple skin and a General Radio Impedance Bridge at 1 kHz; they found the electrical resistance of bruised tissue is lower than unbruised tissue. Puchalski (1994) measured electrical resistance of apple. He used an electrical sensor consisted of two electrodes of 10-4mm dimension (width-length) which were set at a constant distance on a Teflon probe. The sensor pushed into the fruit to measure electrical resistance of the sample between two electrodes. Harker and Forbes (1997) measured tissue resistance and reactance on persimmon fruit at frequencies between 50Hz and 1MHz. Puchalski and Brusewitz (2000) measured electrical resistance of the bruised and unbruised tissue of apple at the frequency of 1 kHz, using a universal impedance bridge and showed that the electrical resistance of unbruised tissue
was more than bruised tissue and larger bruise volume had lower electrical resistance. Jha and Matsuoka (2004) measured changes in electrical resistance of eggplant with gloss, weight and storage period. The results of these investigations have shown the electrical resistance increased with increase in storage period and with decrease in both weight and gloss index of eggplant during storage.

The purpose of this study is to evaluate effects of storage time and weight loss on electrical resistance of apple. In most of the previous research, the electrodes were pushed into the fruit so injured it and thus in each individual test, samples should be changed. In this experiment, especial electrodes for measuring electrical resistance were developed and used without damaging the fruit.

**Material and Methods**

In this research, apple fruit (red delicious) with an average weight 198g is selected. The apples were picked up and stored in 22±2 ºC. During storing time, the experiments carried out in every 12 hours. Weight loss of apples was determined by precision electronic balance with 0.1% accuracy.

To obtain the electrical resistance relationship of apple, an apparatus, originally built at the University of Tehran, was used. Fig. 1 shows the complete system of the apparatus used in this research. The complete unit has overall dimensions of 410 mm in length, 350 mm in width and 330 mm in height. The overall construction of the apparatus was made up of the following main components.

- **Base, (1):** All of the parts are assembled on the base.
- **Square flange bearing, (2):** The rotation of the frame is available by square flange bearing (UCF204).
- **Frame, (3):** Probes and load cell have been set on the frame. The frame can change its angle through the provided pivot. For small fruits, it is recommended to perform the experiment in horizontal property, because the weight of the fruit is not suitable for the existing probe. However, for heavier fruits such as watermelon, if the frame could not hold the fruit in horizontal position, it could be rotated or moved down.
- **Probes, (4):** Probes were constructed from four parts; regulating screw, Circular nut, chamber, and copper plate. These components are connected to the frame by a regulating screw.
  - **Regulating screw:** This is adjustable on the frame. The Probes are adjustable to appropriate distance to match the size of apple, by the regulating screw.
  - **Circular nut:** Circular nut was placed on frame and it was made of polyethylene. It was fixed to the copper plate on the chamber.
  - **Chamber:** The plate electrodes, as insulator parts, were placed between circular nut and chamber. Also the circular nut and the chamber provide a cavity so that the copper plate electrodes can ignore the fruit curvature. The chambers push the electrodes on fruit.
  - **Copper plate electrodes:** Two copper plate electrodes with 0.03 mm thickness and 140 mm in diameter were used for electrical resistance measurement in this experiment. The thickness of plate electrodes provided a suitable solidity and flexibility for applying force. The diameter of the copper plate is bigger than internal diameter of the circular nut (about 4mm) thus, it has enough flexibility following the fruit curvature.

![Fig. 1 The schematic of the apparatus](image-url)
Load cell (5): The force was measured with a beam type load cell (DBBP, Bongshin, Korea, 100N capacity) equipped with a digital weighing indicator. The force was adjusted about 1±0.2 N. The load cell connected to the indicator. Therefore, in every experiment, the applied force on the fruit was adjusted manually. In this experiment, constant forces were applied and thus, there was a similar connection between fruit and copper plate.

As mentioned above, the applied forces on the apples were constant through this experiment. Initially, the tissue impedance components were measured by using a function generator and an oscilloscope (Zhang and Willison (1991), Harker and Dunlop (1994). Alternating current at frequencies between 50 Hz and 1 MHz was passed through the tissue samples. Impedance characteristics were determined from the dimensions of an ellipse traced on the oscilloscope. In later work, impedance characteristics were determined using LCR meter. In this experiment, electrical resistance of apples was measured with LCR Meter (41R, Lutron, Taiwan). The LCR Meter was operated at two frequencies, 120 Hz and 1 kHz. This method is simple and accurate. The basic accuracy of LCR Meter is due to the lower resistance and capacitance 0.5% and 0.7%, respectively. Electrical resistance measurements were performed at two frequencies; 120 Hz and 1 kHz.

Results and Discussion

The variations in electrical resistance, during 50 days of storing period, are shown in Figure 2. The mean of volumetric moisture content at the beginning of the experiment appeared to be 0.81 and at the end of the experiment (after 50 days) was 0.77. The weight loss was caused by decreasing moisture content, during the storing period.

Figure 2 shows the relationship between electrical resistance of tissue and passed time by apple. At frequency 1 kHz, the mean values for the samples during storage time of 50 days at 22±2˚C varied from 72.58 kΩ to 138.88 kΩ. The electrical resistance $E_r$ decreased with storage period $S_p$. At frequency 120 Hz, the mean values of electrical resistance for the samples varied from 442.81 kΩ to 1002.71 kΩ. The electrical resistance $E_r$ decreased with storage period $S_p$ (Fig. 3).

As Figure 2 indicate, the rate of decrease diminished slowly with the storage period and tended to be flat after 25 days of storage. The major reason for the increase of resistance may be a decrease in the moisture content of fruits in a similar pattern during storage due to continual transpiration (Jha and Matsuoka, 2004).

The sharp decline of electric resistance of the apple, during the early storage time, and the following moderate decrease, can be attributed to the fruit moisture content effect in a similar pattern. As the storing...
time increases, due to the continual transpiration (Jha and Matsuoka, 2004) the fruit weight and accordingly, the moisture content decreases.

![Graph showing electrical resistance in relation to weight measured in 1 kHz and 120 Hz](image)

The electrical resistance varied inversely with change in weight of apple during storage for 50 days at 22±2°C (Fig. 3). Loss of water during storage increased the electrical resistance of apple because of the percentage increase in the mass of dry matter, a bad conductor of electricity, during the storage period. The best form of equation fitted to the data of electrical resistance \( E_r \) and the weight, \( W \), in g during storage, was found to be quadratic (correlation coefficient of 0.95 at frequency 1 kHz and correlation coefficient of 0.87 at frequency 120 Hz).

The third degree equation relationship between electrical resistance and storage time was observed for apple. The results indicated that, the weight of the apples in this experiment, decreased linearly with increase in storage period. Water loss of the whole fruit also contributes to mobile ions concentration increasing when ripening. In general, the increasing of ions concentration in the electrolyte of the fruit leads to the decreasing of resistance (Liu, 2006). However, highly concentrated solutions do not follow this pattern; they reveal the opposite trend instead. Therefore, based on these experiments, it is believed that the concentration of ions in fruit becomes very high during ripening.

This investigation indicates that the electrical resistance measurement has a great potential in assessing fruit ripening and forecasting the length of fruit storage.

By combining the apple’s humidity changes with the resistance changes, it is suggested that the storage time consists of three stages, unripe, eating-ripe stage, and overripe stage respectively. In unripe stage, physiological development and electrical resistance increase. In eating-ripe stage, the moisture content and the electrical resistance decrease during the storage time. In overripe stage, moisture content would be very low at the end of the period of storage, thus electrical resistance increases.

**Conclusion**

The electrical resistance of apple fruit was measured by developing and employing special electrodes. This was performed without any physical damage to the fruit. The electrical resistance decreased during the storage time by third degree equation. The results also indicated that, the weight of apple decreased linearly with increase in storage period.
References


