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Findings

This work addresses the problem of quality detection by utilizing the capacitive sensing technology panoramically. This research is a comprehensive work on various facets of capacitive sensing which includes drop sensing technique for quality analysis of milk, development and testing of dynamic milk quality detection, design and simulation of various structures of various capacitive sensors to optimize the dimensions for particular applications, development and testing of three different types of capacitive sensors for intravenous fluid detection in IV chamber to prevent retraction of blood, development of capacitive moisture sensor using graphene oxide sensing film, and temperature capacitive sensor using polydimethylsiloxane (PDMS). In the first work, the drop sensing technique is explored for the healthcare application as the preliminary experiment. The exhaustive experiments performed with the three fabricated capacitive sensors with different electrode geometries (cylindrical cross, semi-cylindrical parallel plate and circular parallel plate) manifest the capability of the proposed sensor to effectively detect the presence of IV drops. The experiments were also performed with four different types of fluids (NS, DNS, RL, and 5D). The shift in capacitance value while the drop passes through the space between the electrodes is acquired in terms of capacitive peaks using the AD7150 DAQ card. The distinctive peak enables to count the droplets, readings are highly precise (0.036%), and drift-free, and the drip rate is 0.4 m/s (cross-capacitive). As the IV fluids are ionic liquids which contain salts, therefore, they have similar compositions, hence the dielectric constants do not vary much making it difficult to differentiate them. Through the careful and detailed analysis of data, the thesis demonstrates that the capacitive sensors have the potential to detect the drop of IV fluid. This work established the prospect of drop sensing for other applications.

After the initial experiments with IV fluids, drop sensing is utilized for adulteration detection in milk. Before conducting the experiments, a simulation study was conducted and sensor electrodes were designed using Ansys Maxwell software to optimize the dimensions of the sensor. Four different common adulterants namely tap water, urea, whey, and detergent are tested with packaged milk (Full fat and Skimmed). The samples were prepared for different concentrations of adulterants and experiments were performed using the fabricated capacitive sensor. The change in the dielectric property of the milk with a concentration of adulterants is reflected in terms of the change in the capacitance value of the sensor. The precise experimentation and meticulous data analysis of the obtained results for all the adulterants clearly indicate the capability of the sensor

to differentiate the different percentages of added adulterants. The proposed system is capable of differentiating pure milk from adulterated milk precisely. The increasing and decreasing trend in capacitance change indicates the variation in the amount of adulteration. Various parameters like pH, EC, TDS and temperature were measured using handheld devices before testing each sample to validate the trend in the capacitance value with available electrical methods of milk quality detection. The designed sensor requires a few test samples drops for testing, and the measurement system comprised of fast data acquisition card (AD7150, expanded measurement uncertainty (u_m) ± 2.9 fF) procured from Analog Devices. It is quite sensitive to the adulterants and the response is precise with a repeatability index of 0.008%. Moreover, water adulterated milk samples (full fat and skimmed) were also analyzed as preliminary testing by filling a square-shaped cross sensor. The parameters impedance (Z), phase angle (θ), capacitance (C), and Nyquist plot (Z' vs Z'') were acquired using an impedance analyzer for the frequency range of 1 kHz to 100 kHz. The filling technique requires a larger quantity than the proposed drop sensing capacitive technique, the impedance measurement has been significantly researched, hence, some experimental studies have been conducted on impedance measurement with tap water as an adulterant in milk.

Furthermore, some of the environment parameters i.e., humidity and temperature are also measured. For humidity measurement, a parallel plate capacitive sensor is fabricated with a silver conducting electrode. The nanocomposite layer of graphene oxide and PVA is used as the sensing film in this work. The unique properties of graphene oxide are explored in moisture measurement applications. The fabricated sensor offers significant sensitivity at low moisture (ppm) and is also suitable for humidity measurement in the %RH range. The sensor has the potential to be used in various applications, especially in food processing and storage. For the temperature measurement, a linear capacitive temperature sensor is fabricated. Polydimethyl Siloxane (PDMS) is used as the sensing material. It is a hydrophobic, biocompatible material; therefore, it is suitable for various biomedical, healthcare, food and beverage processing and refrigeration applications like cold storage. The developed sensor has demonstrated a high potential for temperature sensing in the range of 20- 200 °C. The sensor can be used in humid environments due to the use of PDMS. The fabricated sensor can be utilized in applications which are temperature-sensitive.

This thesis summarizes the efficient use of a novel drop sensing technique using the capacitive sensor in the applications of milk quality analysis. An instant detection system using a few sample drops of milk (beverages) for quality detection is developed. The drop-based technique was extensively explored through experiments on IV fluids prior to test for adulterants in milk. This research establishes the effectiveness of drop sensing techniques for various applications. A few other environmental parameters like humidity and temperature are also measured using capacitive sensing techniques with highly sensitive fabricated sensors.