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1-N-1 Sensor to Detect Whey Adulteration of Milk

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Abstract

Whey is added as an adulterant in to the pure milk to increase the volume of milk. In this study a rapid method has been developed to detect adulterated milk by adding liquid whey using a non-destructive sensing system that uses interdigital capacitive (IDC) sensors. We developed an advanced method using four 1-n-1 (1-1-1, 1-3-1, 1-5-1, and 1-11-1) IDC sensors to detect liquid whey adulteration in pure full cream milk by fringing field emissions using coplanar electrodes. This IDC sensor measured this whey-mixed milk sample with a setup that incorporates a capacitance to digital converter and a microcontroller to display the digital output. This IDC sensor is fabricated on copper-cladded printed circuit boards (PCBs) due to its cost effectiveness, with 70% metallization ratio. The structure of an IDC sensor is analyzed using COMSOL Multiphysics software. We examined five different concentrations (10%, 20%, 30%, 40%, and 50%) of whey-adulterated pure milk in each 50 ml sample. The proposed sensor provides a promising tool for analysis of liquid whey in milk samples. All four sensors capacitance values exhibit a nearly linear correlation with milk's various levels of whey adulteration. The sensor is affordable, lightweight, easy to construct, and convenient. Both simulation and experimental methods have shown that Sensor 1-11-1 has the highest sensitivity.

Keywords: Interdigital Capacitive Sensors, Liquid Whey, Milk Adulterations, Non-Destructive Testing, Sensor Modelling.

Introduction

A highly rich in nutrients diet, animal-based milk contains 3.5% protein, 3% to 4% fat, and 5% lactose. Its essential minerals, including calcium, magnesium, selenium, riboflavin, and vitamin B12, make it a significant component for the human diet (1). According to the annual report 2023-24, through its Department of Animal Husbandry and Dairying, India remains the world's largest milk producer (2). The government has implemented various initiatives to boost livestock productivity, leading to substantial increases in milk production. In 2021-22, milk production was 222.07 million tonnes, rising to 230.58 million tonnes in 2022-23, reflecting an annual growth rate of 3.83%. The per capita milk availability in 2022-23 is approximately 459 grams per day (3). Milk and milk product adulteration is common for a variety of reasons, including rising profit margins, social moral decay, a gap between supply and demand, low consumer purchasing power, competition for new markets, the physical characteristics of milk, a smaller percentage of the organized dairy industry in the dairy industry, a lack of appropriate, quick, and reliable tests etc. (4). In general, milk is contaminated with formaldehyde, rice flour, glucose, water, turmeric, whey, and cane sugar. It is then neutralized with caustic soda, caustic potash, sodium carbonate, lime water, and other substances (5). The rising demand for milk in India has led to the dairy business dealing with whey adulteration, which changes the physicochemical characteristics of milk and the quality of its food (6). According to reports of the irresponsible use of whey protein, when consumed in large quantities or for a long period of time, they can have negative health impacts such as stomach pain, cramps, decreased appetite, nausea, sore throat, headache, exhaustion, acne, kidney and liver damage (7). Additionally, consuming whey protein is odd from a nutritional perspective, and there is no natural substitute (8). Addition of liquid whey slightly increases the acidity of natural milk, resulting in a lower pH value. Additionally, some unscrupulous cheese producers use inexpensive muriatic acid, which is form of hydrochloric acid, used to produce cheese from milk, leads to severe health concerns

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(9). During the cheese-making process, the rennet enzyme breaks down the K-casein protein in milk by splitting the peptide bond between phenylalanine 105 and methionine 106. This enzymatic action produces two fractions: para-K-casein, which forms the solid curd, and casein glycomacropeptide (GMP), which remains in the liquid whey. Simply put, this process separates milk into solid curds and liquid whey. GMP, containing 64 amino acids and specific threonine residues linked to short carbohydrate chains via O-glycosidic bonds, is hydrophilic and stays dissolved in the whey, whereas para-K-casein precipitates to create cheese (10). Normally, GMP is present in very low concentrations in bovine milk, making it an effective marker for detecting milk adulteration. This is because high GMP concentrations indicate whey adulteration, as GMP levels in whey are approximately tenfold greater than those found naturally in cow's milk during hydrolysis.

The use of liquid whey as a milk adulterant offers dual advantages for fraudsters. Firstly, it is readily available to cheese manufacturers in large quantities, making it an inexpensive and accessible option for milk suppliers. Secondly, liquid whey retains several natural properties of milk, making it easier to prepare synthetic milk that closely resembles authentic milk. This allows adulterated milk to mimic the appearance of natural milk effectively (11). Consequently, adulterating milk with liquid whey has become a widespread malpractice, particularly in areas where large amounts of cottage cheese are produced daily to create various sweets (12). This poses a significant challenge for dairy companies that source milk from numerous suppliers (13). They require a simple, reliable, and biocompatible sensing system for quality monitoring in their milk supply chain to address this.

Spectroscopic methods, including Fourier-transform infrared (FTIR) spectroscopy and ultraviolet-visible (UV-Vis) spectroscopy, are used to detect changes in milk's chemical composition caused by whey adulteration (14). These techniques have limited sensitivity for low levels of adulteration and require expensive equipment and trained personnel, which also causes interference from other adulterants to complicate detection (15). Chromatographic methods, such as High-Performance Liquid Chromatography (HPLC) and Gas Chromatography (GC), are used to identify and quantify specific whey proteins or carbohydrates. These methods are often time-intensive and labor-intensive, requiring skilled technicians, High operational costs, and specialized instruments (16).

The protein-based assay technique detects whey proteins like β-lactoglobulin or glycomacropeptide using immunoassays such as ELISA (enzyme-linked immunosorbent assay). These techniques required expensive reagents and kits and were not suitable for large-scale or on-site testing (17). Enzymatic tests measure specific enzymes or biochemical reactions associated with whey proteins. However, these tests are limited to detecting known enzymatic markers, and results can vary with storage and handling conditions (18). In electrical conductivity measurement, Adulteration with whey increases milk's electrical conductivity due to added ions, but the drawback of this test is its low specificity, as conductivity changes may be due to other adulterants and Ineffective at detecting small amounts of whey adulteration.

This study proposes a non-destructive IDC sensor for detecting whey in milk sample. The sensors were designed and simulated for various structures using the COMSOL Multiphysics software. The sensors were subsequently fabricated to measure capacitance to validate the simulation results. Four sensors with varying 1-n-1 electrode structures, including 1-1-1, 1-3-1, 1-5-1, and 1-11-1, were designed, analyzed, simulated using the finite element method, and fabricated to measure the capacitance of milk. A cost-effective sensing system utilizing a microcontroller is proposed. The sensor provides instantaneous dynamic capacitance change and is simple to construct, operate, and maintain at a reasonable cost. It is also portable and convenient to use in the field. The capacitance values of all four fabricated sensors exhibit a nearly linear correlation with different amounts of adulterations of whey in milk. Experimental results show that Sensors 1-5-1 and 1-11-1 demonstrate higher sensitivity compared to the other two.

Methodology

This section discusses the theoretical aspects of the IDC sensor, design and simulation, fabrication, and experimental setup used in the proposed work.

Theoretical Aspects

Interdigital refers to a periodic pattern of parallel in-plane electrodes that resembles a digit like, comb like, or finger like and is used to increase the capacitance of the electric fields that pass through the material sample or sensitive coating (19).

In Figure 1, the coplanar IDC fringing-field capacitor can be considered a capacitor with several comb-patterned capacitor plates on the same plane. The common set of positive and negative electrodes that connect each copper finger consists of "N" positive electrode fingers and "N-1" negative electrode fingers spaced at predetermined intervals. Where finger width is "w", finger length is "L," gap between adjacent fingers is "g," and the distance between consecutive fingers on the same side is "λ" (20). The flame-retardant (FR4) substrate is used to create the coplanar copper cladding 1-n-1 IDC structure, in which one side of the substrate can be used for the interdigital structure while on another side, a metal shield is placed (21).

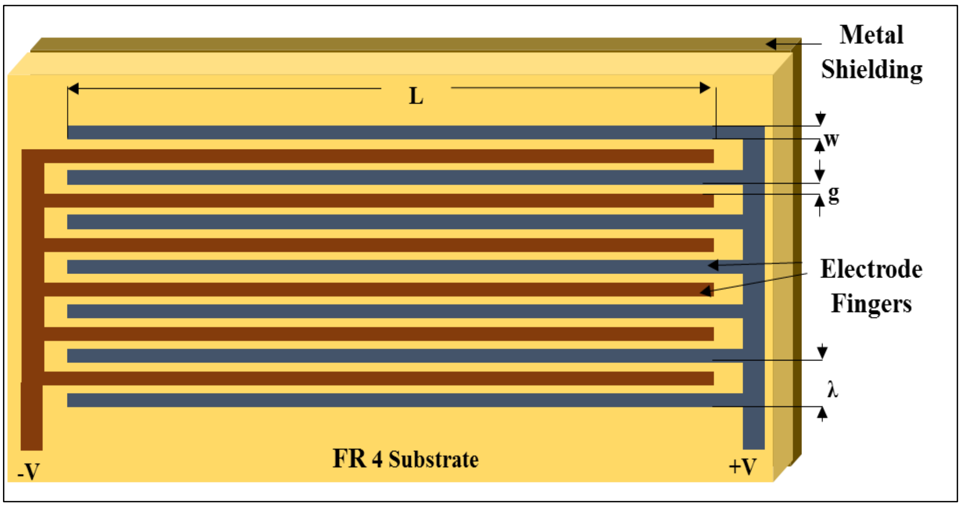

Figure 1: Interdigital Electrode of IDC Sensor

In Figure 2, the 3D geometry of four different configurations are regarded as 1-1-1, 1-3-1, 1-5-1, and 1-11-1 of 1-n-1 IDC sensors with 37 electrodes, where the 1-1-1, 1-3-1, 1-5-1 and 1-11-1 structure have 19, 10, 7, 4 number of positive electrode and 18, 27, 30, 33 number of negative electrodes respectively (22). Figure 3 shows that the parallel plate capacitor and the IDC sensor operate on the same basis. From Figure 3(A), it is seen that when copper shielding is placed on the opposite side of the interdigital pattern, the electric field line moves only the sample under test (SUT) side, which gives better utilization of the fringing field, in Figure 3(B) the electric field lines move in both sides. The IDC sensor's electrodes make contact with the SUT (in our case, milk with whey adulteration) with a dielectric constant of ε_d. It is attached to a measuring circuit and serves as a dielectric between electrodes (23). A potential difference between the electrodes that are positive and negative will cause the electric field to flow from the finger of the positive electrode to the negative electrode that is entering the SUT. As a result, when the amount of whey adulteration in pure milk changes, the observed capacitance changes.

Utilizing network analysis to assess the equivalent circuit, the capacitance of a 1-n-1 sensor can be expressed generally as follows:

$$C_{CIE,1-n-1} = \sum_{\delta=1}^{\frac{(n+1)}{2}} \left[\frac{2C_{I\delta}.C_{E\delta}}{C_{I\delta}+C_{E\delta}} + (\alpha-2)C_{I\delta}\right] \qquad [1]$$

where the variable "n" signifies the number of Negative Electrodes (NE) positioned between two successive Positive Electrodes (PE). "α" denotes the total number of positive electrodes (24). It should be mentioned that this statement is only true when the first and last electrodes are functioning as PEs. Due to symmetry considerations, it is possible to evaluate the sum of the capacitance of one layer using two different forms of capacitance: first $C_{I\delta}$, which is equivalent to one-half of an inner electrode's capacitance in relation to the ground voltage, and second $C_{E\delta}$, the capacitance between the external electrode and the ground.

The value of $C_{I\delta}$ and $C_{E\delta}$ depends on the dielectric's height (h_d) in relation to the electrodes' spatial wavelength λ.

If, $h_d > \frac{\lambda}{2}$

$$C_{I\delta} = \varepsilon_d C_{I\delta}(h_d) \quad [2]$$

$$C_{E\delta} = \varepsilon_d C_{E\delta}(h_d) \quad [3]$$

If, $h_d < \frac{\lambda}{2}$

$$C_{I\delta} = (\varepsilon_d - 1)C_{I\delta}(h_d) + C_{I\delta}(\infty) \quad [4]$$

$$C_{E\delta} = (\varepsilon_d - 1)C_{E\delta}(h_d) + C_{E\delta}(\infty) \quad [5]$$

where ε_d is the dielectric constant of the electrode's top layer. $C_{I\delta}(\infty)$ and $C_{E\delta}(\infty)$ are the interior and exterior geometric capacitance for a layer that is infinite.

The Partial-Capacitance (PC) method and Conformal-Mapping (CM) method have been used to estimate the capacitance $C_{I\delta}(h_d), C_{E\delta}(h_d), C_{I\delta}(\infty) and\ C_{E\delta}(\infty)$ (25).

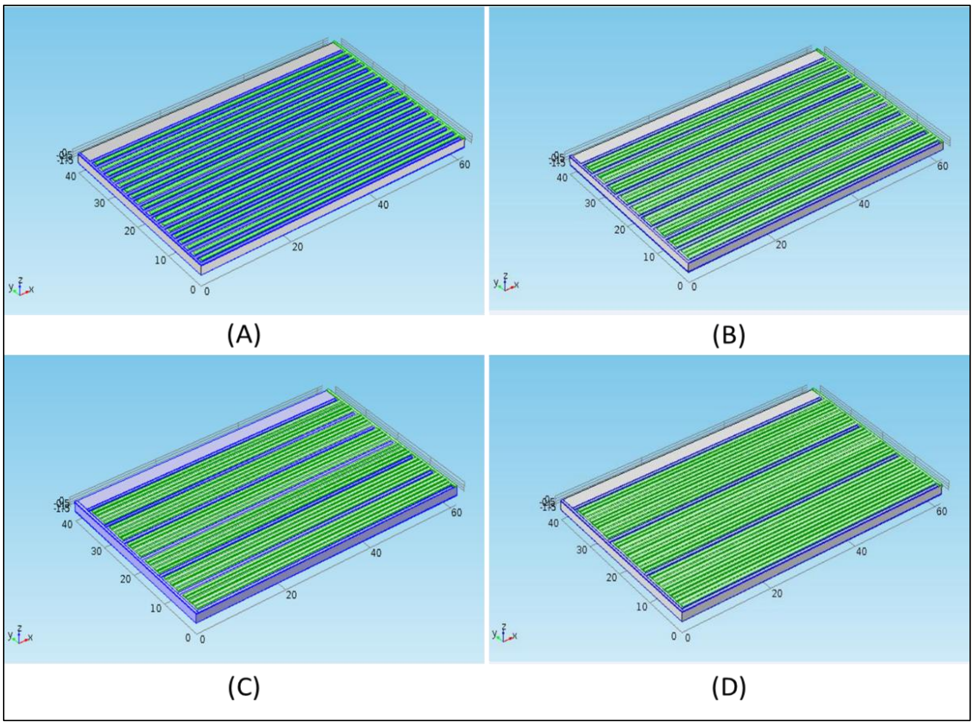

Figure 2: 3D Geometry of Four Possible 1-N-1 (A) 1-1-1, (B) 1-3-1, (C) 1-5-1 and (D) 1-11-1 IDC Structure with 37 Fingers

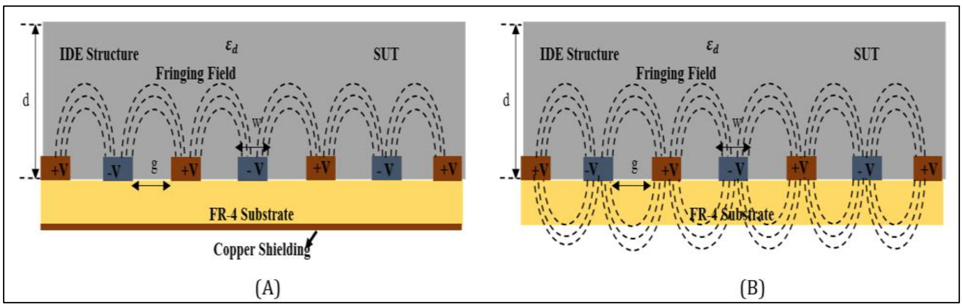

Figure 3: Schematic of Sample Measurement for an IDC Sensor and Fringing Field Effect in (A) The SUT Side and (B) Both Sides of the Substrate

The metallization ratio (η_δ) and the height-to-wavelength factor (r_δ) are two non-dimensional parameters that affect the sum of the positive and negative electrode capacitance in interdugital patterns (1-1-1, 1-3-1, 1-5-1, and 1-11-1).

Defined as

$$\eta_\delta = \frac{w}{w+g} = \frac{2w}{\lambda_\delta} = \frac{\eta_1}{\delta} \quad [6]$$

and

$$r_\delta = \frac{h_d}{2\delta(w+g)} = \frac{h_d}{\lambda_\delta} = \frac{r_1}{\delta} \quad [7]$$

where λ_δ is the electrode's spatial wavelength (ESW) and h_d is the dielectric layer height (as measured from the electrode plane); the ESW for 1-n-1 pattern (where n ≠ 1) can be expressed as:

$$\lambda_\delta = 2\delta(w+g) \quad [8]$$

Where, $\delta\ (= 1, 2, \ldots. \frac{(n+1)}{2})$

Design and Simulation

The COMSOL study was performed to determine how the ideal value of ground electrodes between two interdigitated positive electrodes leads to the maximum measurement sensitivity. One, three, five, and eleven negative electrodes were analyzed between two positive electrodes (26). Each electrode was simulated to be the same length (60 mm), width (700 µm), gap between electrodes (300 µm), metallization ratio (70%) and wavelength (2 mm). Further study was carried out to evaluate the electric field distribution for each of the four sensors. The electric field distribution results for each sensor are shown in Figure 4. As for the 1-11-1 sensor, at nearby electrodes, the electric field strength is greater, but as it moves toward the center, it weakens; additionally, Figure 4 illustrates how the intensity of the electric field drops with increasing height. The 1-5-1 sensor, 1-3-1 sensor and 1-1-1 sensor simulation had the same outcomes, but with a different pattern. It has been seen that a better electric field distribution but comparatively weaker field strength can be achieved by placing a suitable number of negative electrodes between positive electrodes. The strength of the electric field is sufficient to interact with the sample under test. In contrast to other sensors, the electric field distribution for the 1-11-1 sensor was uniform.

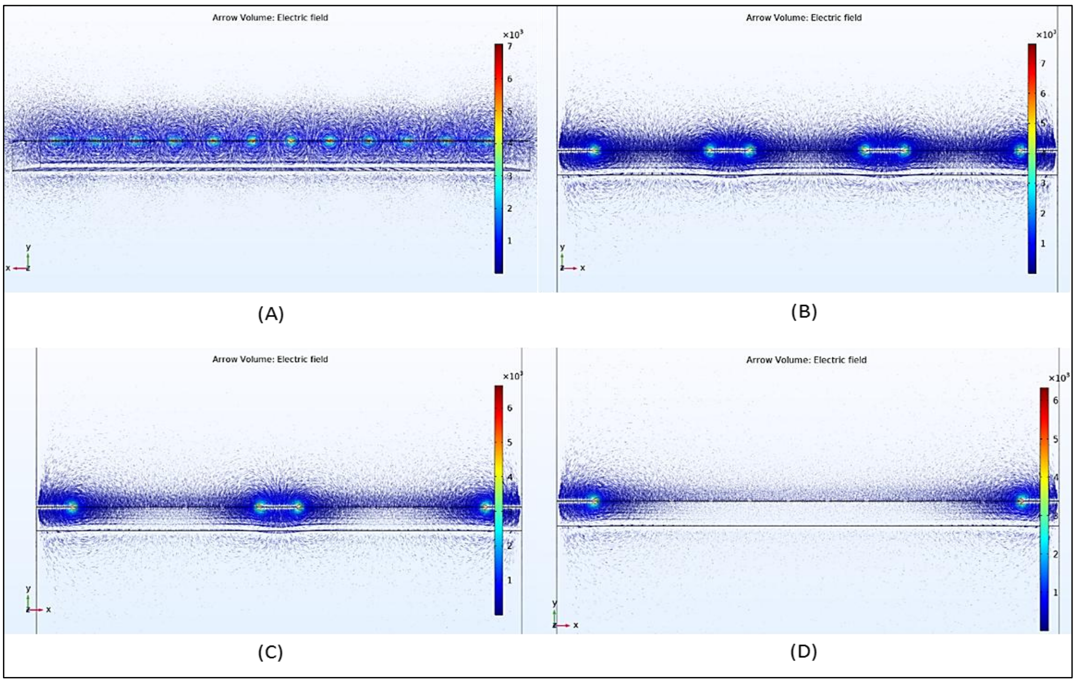

Figure 4: Electric Field Distribution in (A) 1-1-1 Sensor (B) 1-3-1 Sensor (C) 1-5-1 Sensor and (D) 1-11-1 Sensor Configuration

This uniformity will help improve sensor performance. The calculated capacitance value in air for every sensor obtained from the simulation is displayed in Table 1. The 1-1-1 pattern sensor exhibits a low signal height and good signal strength, while the 1-11-1 pattern sensor displays the reverse. Therefore, for moderate signal strength and signal height, 1-3-1 or 1-5-1 may be the best choice. Further analysis was conducted for all fabricated sensors by keeping the sample into the model.

In this analysis, the relation between capacitance and various effective permittivity values (from 10 to 70 in intervals of 10) of the sample while maintaining the same parameters are observed. From Figure 5 (A)-(D), it can be observed that as when the sample's permittivity increased, it also increased the capacitance.

Table 1: Calculated Capacitance from IDC Sensor Modeling with COMSOL Multiphysics

1-n-1 IDC Sensor	Simulation Parameters			Calculated Value
Structure	**Positive Terminal**	**Negative Terminal**	**Shielding Terminal**	**Capacitance in Air (pF)**
1-1-1	+3.5 V	0 V	-3.5 V	63.4
1-3-1	+3.5 V	0 V	-3.5 V	35.3
1-5-1	+3.5 V	0 V	-3.5 V	25.1
1-11-1	+3.5 V	0 V	-3.5 V	14.8

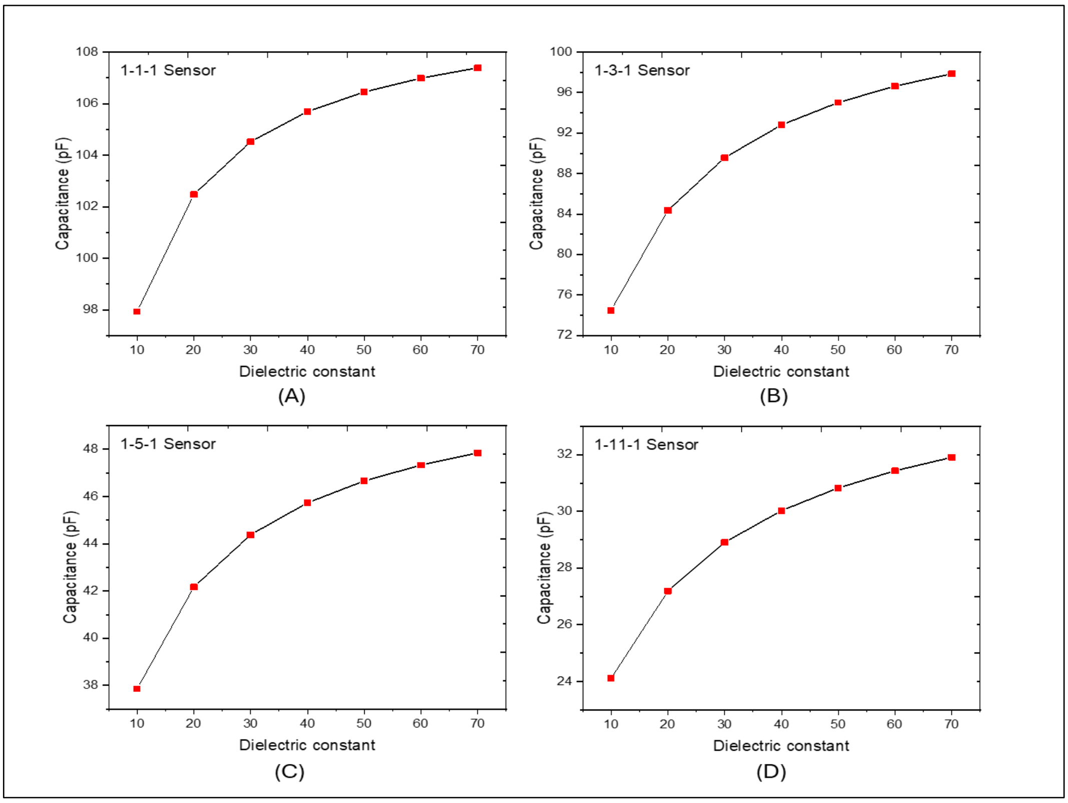

Figure 5: Variation in Capacitance with Change in the Dielectric Constant of SUT in (A) 1-1-1 Sensor (B) 1-3-1 Sensor (C) 1-5-1 Sensor and (D) 1-11-1 Sensor Configuration

Fabrication of 1-N-1 IDC Sensor

Four coplanar IDC sensors of different structures such as 1-1-1, 1-3-1, 1-5-1, and 1-11-1 of 37 fingers and 70% metallization ratio are fabricated on PCB substrate. For PCB substrate, copper-cladded FR4 material is used. An electronic design automation (EDA) software, EAGLE, was used for PCB design. Acetone and ethanol were used to clean the PCB substrate properly by keeping the substrate with a solution in the ultrasonic bath. Further, the substrate was cleaned in distilled water, and at last, it was cleaned with sulfuric acid to remove the oxide layer. After cleaning the PCB substrate, dry nitrogen gas was used to dry the PCB substrate.

The coplanar 1-1-1, 1-3-1, 1-5-1, and 1-11-1 IDC electrode structures were created using an inkjet printer on photo paper. Then, the thermal heating press was transferred to the photo paper print on the PCB copper layer. After that, this printed PCB substrate was dipped in a solution of $FeCl_3$ for a short interval.
Now, the copper exposed section was etched away. Once again, distilled water, acetone, and ethyl alcohol were used to completely clean the substrate and it was dried in a nitrogen gas flow (27). The photograph of the four fabricated 1-n-1 IDC sensors is shown in Figure 6. The dimension of the all four fabricated sensor were 61.5 mm X 40 mm. the length and width of the electrode was 60 mm and 700 um respectively. The gap between the electrode was 300 um, the thickness of the electrode and substrate was 35 um and 1.57 mm respectively.

Figure 6: Fabricated Coplanar IDC Sensor in 1-1-1, 1-3-1, 1-5-1 and 1-11-1 Configuration

Experimental Setup

Figure 7 depicts the experimental set up used to measure sensor capacitance. The equipment used in the setup included a Proto-Central FDC1004 breakout board, a digital infrared thermometer, a glass container, a disposable syringe, a laptop and ESP-32 (28). The Proto-Central FDC1004 breakout board contains the Texas Instruments FDC1004 IC (capacitance-to-digital converter) to measure the sensor's capacitance (29). The capacitance measurement range, resolution, maximum offset capacitance, and the output data rate of the IC are +/- 15 pF, 0.5 fF, and 400 samples/second. The current consumption of the IC in active and standby mode are 750μA and 29μA respectively. The board is connected to the SDA and SCL pins of the ESP32, which are GPIO21 and GPIO22, using the I2C standard interface. The interdigitated IDC sensor was affixed to the outer bottom surface of a glass container, with a copper coating on the exterior and the Interdigital pattern facing inward. A shielded cable connected the sensor to the board. An experimental study was carried out on prepared milk samples added with whey as adulterants under controlled conditions: a room temperature of 25 ± 4 °C and relative humidity of 46 ± 2 %RH. Positive Electrode, Negative Electrode, and Shielded Electrode of the fabricated Sensor are connected to channel 1 (CIN1), ground (GND), and shield 1 (SHLD1) of the FDC1004 breakout board (30). A shielded cable was used to connect the sensor and the board to avoid stray capacitance.

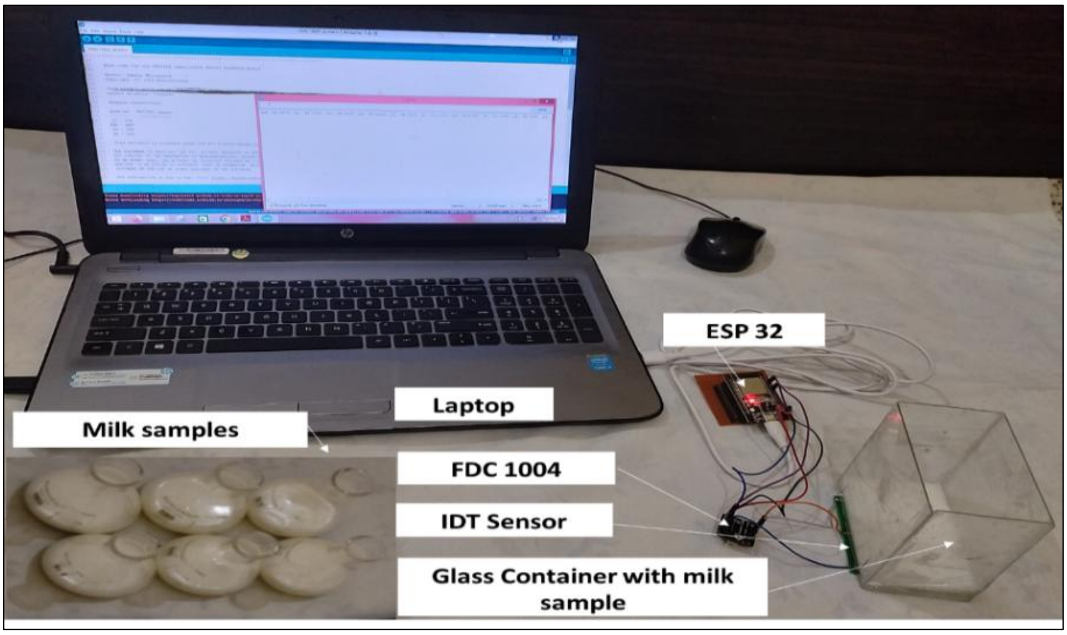

Figure 7: Experimental Setup for Measuring Milk Adulteration with Whey

Results and Discussion

The byproduct of cottage cheese is called whey. Whey is added as an adulterant to the milk sample to increase the volume of milk. To make whey, 200 mL of pure milk at 65 °C was mixed with 1.2 mL of HCl. The solid, white portion of the milk was separated from the light green whey. Next, the whey was filtered out, and utilized to create milk samples with various whey volume percentages. The packaged full-cream milk that was purchased from Amul Dairy Pvt. Ltd. in India was used to produce the samples. According to the package, every 100 milliliters of milk had 120 mg of calcium, 42 mg of sodium, 5 g of carbohydrates, and 3.2 g of protein. The fat percentage of full-cream milk was 18%. The milk that was purchased from the seller was handled as if it were pure. Six samples of 50 ml, in which one sample is pure milk, and the other five samples are prepared after adding whey as an adulterant. 50 milliliters of pure full-fat milk was put into five beakers for the whey sample processing. Whey was added to pure milk in increments of 10%, 20%, 30%, 40%, and 50%. Each solution was agitated for five minutes using a magnetic stirrer to achieve homogeneity. To maintain an 8^0C temperature, the samples were refrigerated. The response of all four fabricated IDC sensors was then measured using these samples. Once again, a pure milk sample was used for the initial experiment, and the sensor was attached to the circuit to obtain the output capacitance. Then, using different samples and fabricated sensors, the experiment was conducted again. Figure 8 (A)-(D) illustrates the change in output capacitance of all four-fabricated sensors for various milk samples. According to experimental findings, as the amount of whey in the milk increases, the output capacitance of each IDC sensor decreases. Therefore, an inverse relationship between electrical conductivity and capacitance with respect to the percentage of whey has been noted in other studies (31). The degree of adulteration has been calibrated in relation to the variations in capacitance, as illustrated in Figure 9 (A)-(D), utilizing the curve fitting technique. This calibrated equation was subsequently programmed into the ESP32 board to quantify the level of adulteration. Figure 10 (A)-(D) illustrate a comparison between the estimated and actual amounts of the percentage of whey in the adulterated milk. The error bar for the final output is also provided for each data point in the same Figure. The accuracy of the prototype sensor has been determined to be less than 2%. The sensor can distinguish between pure and contaminated milk while monitoring changes in the quantity of adulterant.

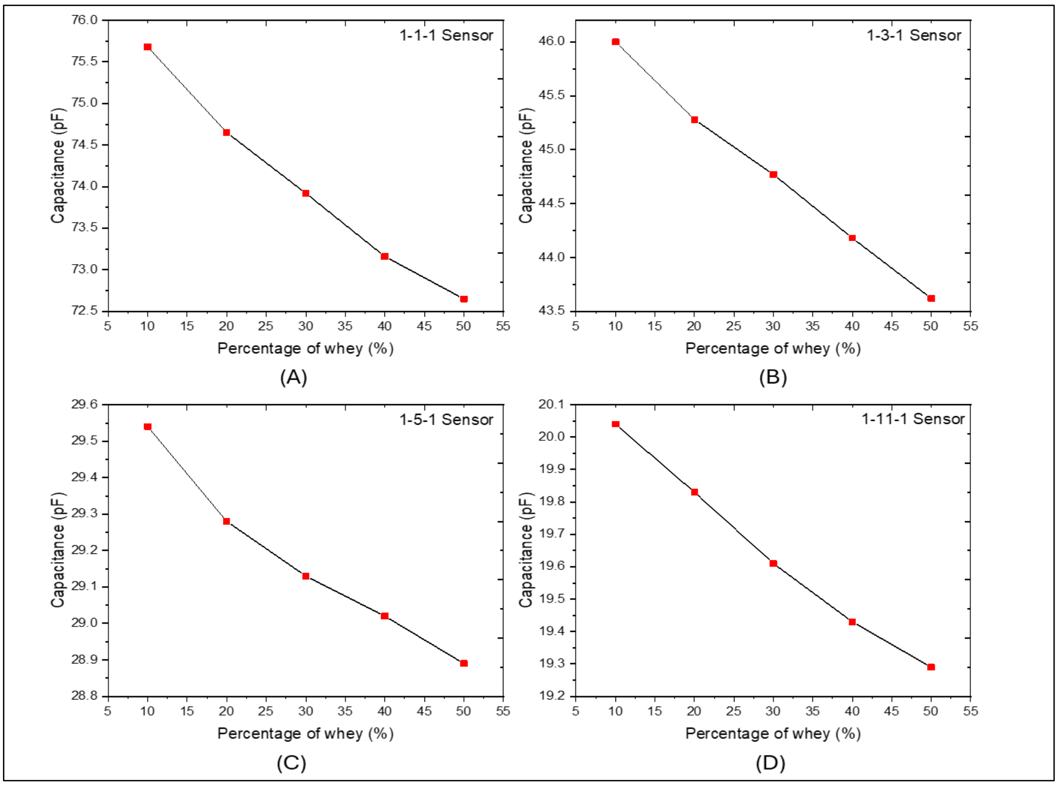

Figure 8: Capacitance Variation Response for (A) 1-1-1, (B) 1-3-1, (C) 1-5-1, and (D) 1-11-1 Sensor Configuration When the Amount of Whey Increases in Pure Milk

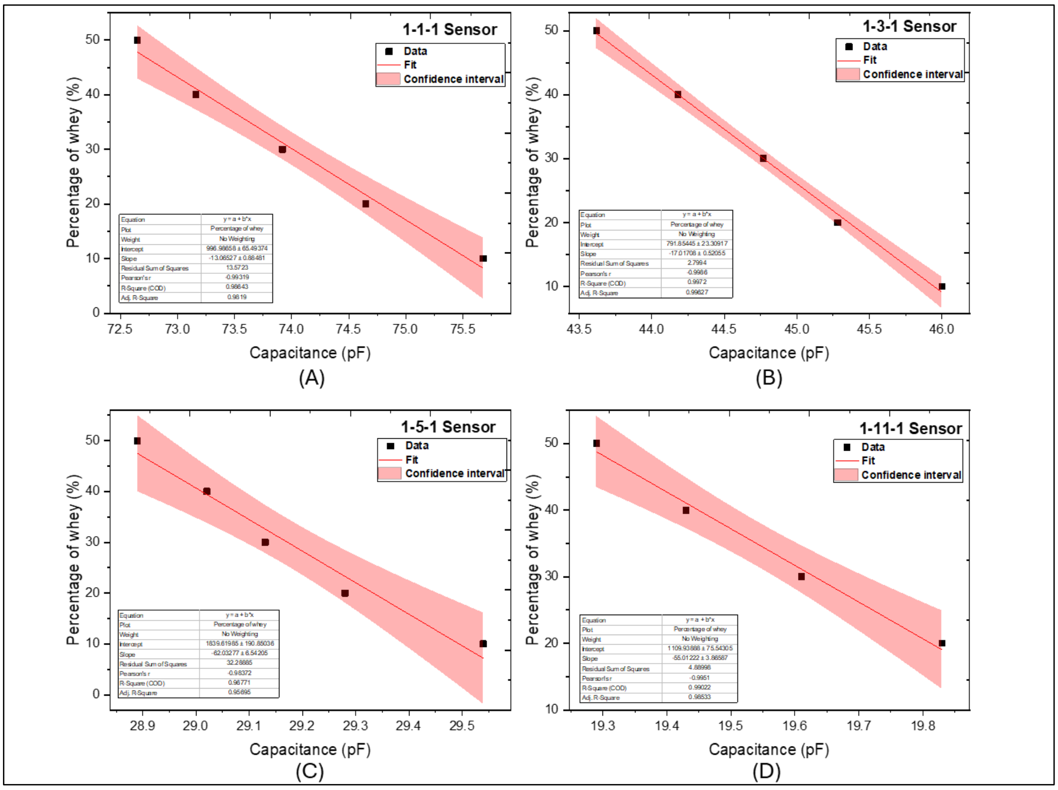

Figure 9: The Linear Fit Curve Shows the Percentage of Whey in Terms of Change in Capacitance. (A) 1-1-1, (B) 1-3-1, (C) 1-5-1, and (D) 1-11-1 Sensor Configurations

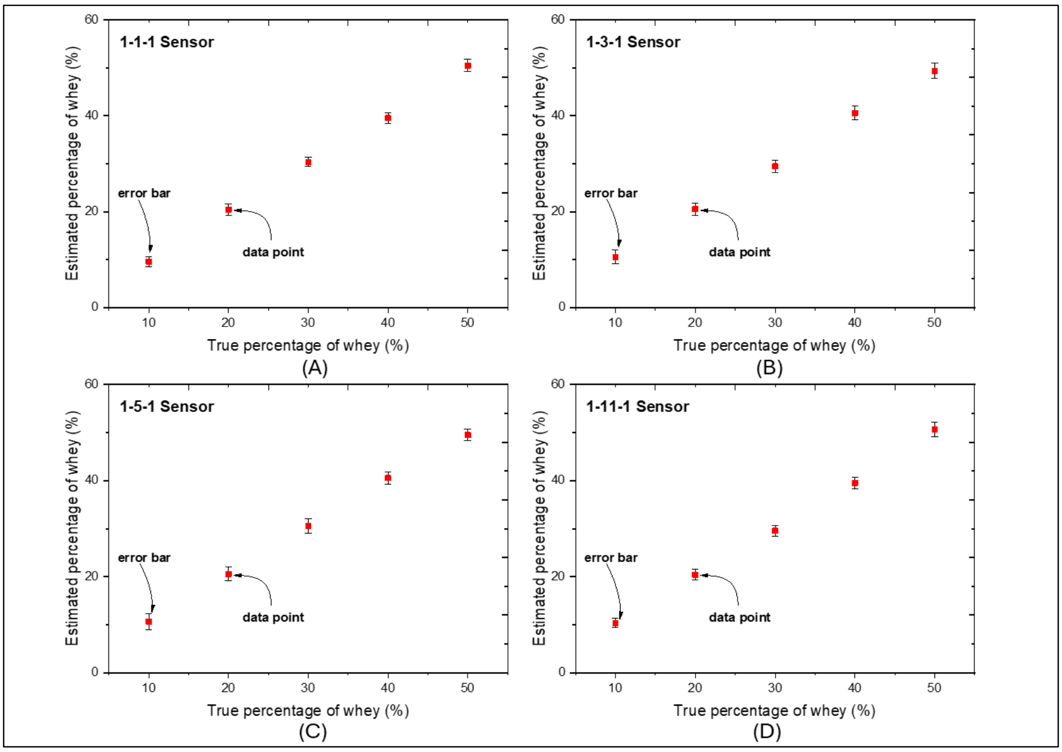

Figure 10: Comparison of Estimated Percentage of Whey from the Proposed Sensor and True Value of the Percentage of Whey. Error Bars Represent Standard Deviation. (A) 1-1-1, (B) 1-3-1, (C) 1-5-1, And (D) 1-11-1 Sensor Configurations

Also, the proposed sensor setup includes a low-power consumption capacitance-to-digital converter (FDC 1004) IC and an IDC capacitive sensor, making it a low-power device. The low-cost nature of the FR-4-based fabrication and its compact PCB form factor support portability.

The sensor data is acquired and calibrated through the ESP32 board. It can then be transmitted wirelessly for remote monitoring through smartphone-based readers, which will be implemented in future work.

Table 2 compares the methods, applicability, and efficacy of the 1-n-1 IDC capacitive sensor system with other methods that are now available.

Table 2: A Comparison between the Proposed Method with Previously Available Conventional Techniques

Reference	**Name of the instrument**	**Method of detection**	**Suitability**	**Disadvantage**
This work	IDC sensor	Fringing field / non-contact detection	Household application	Careful handling is required before retesting
[15]	Spectroscopic	Fourier-transform infrared (FTIR)	Industrial setup/ Lab-based	Limited sensitivity for low levels of adulteration and require expensive equipment
[16]	Chromatographic	High-Performance Liquid Chromatography (HPLC)	Industrial setup/ instrument based	Expertise required for calibration model, costly
[17]	Enzyme based sensor	Based on the piezoelectric sensor	Lab-based	High response time and sophisticated

Conclusion

An essential component of capacitive sensors are interdigital electrodes. In this study, interdigital electrode-based capacitive sensor applications are used. A set of four 1-n-1 IDC sensors have been examined and evaluated. This all four sensors have been modeled using COMSOL Multiphysics software, and an experimental study has been done for all four fabricated sensors. Both methods have shown that Sensor 1-11-1 has the highest sensitivity. The experiments were performed for different amounts of adulteration of liquid whey in pure milk, and it was found that all four fabricated sensors have linear relationships at different amounts of adulteration. The results show that when the amount of liquid whey increases in the pure milk, the output capacitance of all four sensors decreases. The FEA method shows that as the sample's permittivity increased, the capacitance also increased. This FEA study additionally shows that the sensitivity increases for the designed sensor as the number of fingers increases and the gap between the fingers narrows under the same electrode area. Additionally, the height of the electric field increases as the number of fingers between two positive electrodes increases. The number of fingers and the gap between them were the main parameters of the max-field height and the sensor sensitivity, respectively. It is possible to integrate these sensors and their signal processing circuits into a small-volume measurement device to accomplish the measurement of milk quality due to their simple structure and ease of fabrication. Since the proposed sensor has potential for mass production using PCB fabrication facilities and integration with handheld microcontroller-based readout systems, it can be commercialized and deployed in rural milk collection centers. In this study, we concentrated on whey as the primary adulterant of interest. Future research will expand to include sensor calibration against a range of prevalent adulterants, such as water, starch, and detergents. Additionally, we will assess performance under varying temperature and humidity conditions to more accurately reflect practical applications and real-world environments.

Abbreviations

CM: Conformal-Mapping, EDA: Electronic Design Automation, ESW: Electrode's Spatial Wavelength, FR4: Flame-Retardant-4, GND: Ground, IDC: Interdigital Capacitance, NE: Negative Electrode, PC: Partial-Capacitance, PCB: Printed Circuit Board, PE: Positive Electrode, SUT: Sample Under Test.

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Author Contributions

Mohammad Haris Bin Anwar: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Writing—original draft, Writing—review and editing, Mirza Mohammad Shadab: Conceptualization, Validation, Formal analysis, Resources, Supervision, Anwar Ulla Khan: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Writing—original draft, Writing—review and editing, Supervision. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors, Mohammad Haris Bin Anwar, Mirza Mohammad Shadab and Anwar Ulla Khan declare no conflict of interest.

Ethics Approval

Not applicable.

Funding

None.

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