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DEVELOPMENT OF FIBER OPTIC SENSOR FOR MEASURING JAGGERY ADULTERATION

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ABSTRACT

Jaggery, an unprocessed natural sweetener derived from sugarcane, is a staple of traditional meals in many countries. Adulteration with refined sugar is a common problem that lowers its nutritional value and quality. This work highlights the development of an intrinsic fiber optic sensor to detect added sugar impurities in jaggery by destructive testing in a liquid format. This paper presents a fiber optic sensor (FOS) that detects contaminated jaggery using multimodal interference (MMI). The sensor is built using a core multimode fiber (C-MMF) segment with light source LED and phototransistor used with FOS. We draw attention to discovering two main adulterants in jaggery that change its refractive index (RI): the amount of moisture and glucose. Extensive testing contained four concentration ratios: 100:0%, 0:100, and jaggery: sugar. The sensor could detect all concentration intensities, and the measure in jaggery could detect glucose concentrations ranging from 25% to 75% and 100%. The sensor provides a fast, sensitive, and accurate method of detection. This study looks at the sensor's ability to quantify standard jaggery and sugar impurities and how effectively it can identify levels of concentrations of sugar in jaggery solutions. Experimental data indicates that the fiber optic sensor (FOS) is a feasible instrument for quality control since it performs better than conventional testing techniques.

Keywords: Jaggery, Fiber Optic Sensor, Optical Fiber, Jaggery Adulteration.

I. INTRODUCTION

Jaggery, a traditional and natural sweetener, is widely used in culinary practices and has various health benefits due to its unrefined nature. However, adulteration with refined sugars is a persistent problem compromising quality, texture, and nutritional content[1]. Jaggery is a healthy, nutrient-dense substitute for white sugar that promotes conventional farming methods while providing many health advantages. It is a priceless sweetener that merits increased interest in the culinary and health fields due to its lengthy history and natural makeup. We can help rural economies and encourage a healthy lifestyle by investing in the jaggery sector and developing production methods[2]. Traditional testing techniques for jaggery adulteration often involve complex procedures that are not easily accessible[3]. The physical and chemical properties of the extract solution and their absorbance with the help of an LED source, detector and are measured by an intrinsic fiber optic sensor for assessing jaggery quality and detecting sugar adulteration using a destructive testing approach in a liquid format[4]. To assess the sensor's accuracy and reliability in a liquid format using destructive testing[5]. Develop an intrinsic fiber optic sensor capable of detecting sugar adulteration in samples and compare the sensor's performance with the conventional lab method to check the change in concentration change in intensities [6].

Fiber Optic Sensor:

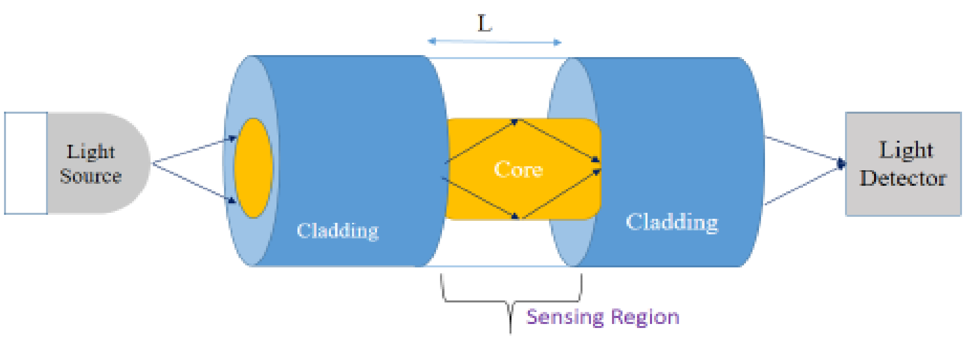

Fig .1 Schematic diagram of intrinsic fiber optic sensor

Usually, the optical fiber cable (FOC) consists of a cylindrical outer layer of FOC is cladding having a refractive index and the inner part is a core having a refractive index (Fig. 1). In (fig.1) with the light source light traveling through FOC as per fiber based properties of light attenuated total reflection (ATR). When light source are launched so that they contact the core-cladder interface at an angle larger than the critical angle, the propagating waves in the core are completely reflected[11].

Fiber Optic Sensor Technology in Food Quality Analysis

Because intrinsic fiber optic sensors can use light interaction to detect even minute changes in chemical composition, they have become extremely effective tools for food quality analysis. There is little research on the use of these sensors for evaluating the quality of jaggery, despite their effective implementation in other fields such as biomedical applications and water quality monitoring[12], [13]. In destructive testing, solid jaggery samples are dissolved in a liquid for in-depth examination. Because it homogenizes the sample, this method has the advantage of enabling precise and repeatable measurements. Destructive testing for jaggery can offer a reliable medium for fiber optic sensor analysis, increasing the precision of sugar impurity detection[14].

II. SENSOR DESIGN AND SYSTEM

In this FOS construct with the help of fiber optic cable 50cm in length, core 50mm, and cladder 125mm. An intrinsic fiber optic sensor based on a multimode optical fiber was used in the meticulously planned sensor system because of its ability to detect changes in liquid samples. The configuration comprised several crucial elements, each chosen to maximize the sensor's sensitivity to sugar molecules[15].

Initially, the light source was a green LED that emitted light at a particular wavelength designed to be very sensitive to sugar molecules. This wavelength was chosen to increase the accuracy of the sensor by guaranteeing that any interaction with sugar would cause discernible changes in the light signal. A key component of the design, the multimode optical fiber was selected because of its great sensitivity to changes in refractive index, which have an immediate effect on light transmission. The fiber's refractive index may be adjusted to precisely record minute variations in the sample solution as its on core [16].

Fiber optic sensors for chemical sensing applications are divided into two groups (intrinsic and extrinsic) [17]. Fig. 2 shows U-shaped FOS based on their absorbance and refractive index, these sensing techniques with various organic and inorganic species detection methods[18], [19]. To increase sensitivity, a cladding was removed and applied to the sensing region of the majority of the sensor. This cladding serves as an interface between the target concentration and the optical fiber core[20].

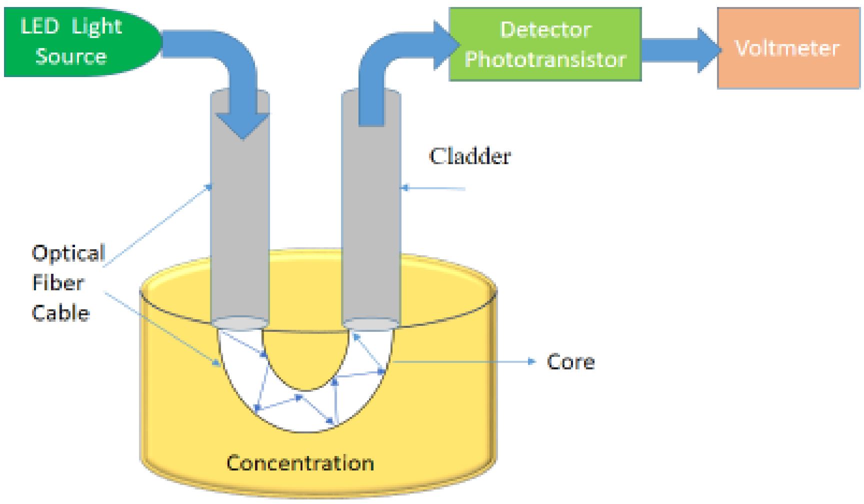

Fig.2 Schematic Block Diagram of U-Shaped Fiber Optic Sensor System

Fig. 2 shows OFC to enable direct interaction with the environment, the U-shaped fiber optic sensor bends an optical fiber into a U shape, exposing the core at the curve. Through evanescent wave coupling, which is extremely sensitive to variations in the surrounding medium's refractive index, some light escapes as it passes through this U-bend. The amount of light lost at this bend is influenced by changes in the surrounding environment, including temperature, fluid content, and chemical composition[21]. This sensor can precisely monitor particular environmental parameters since the residual light, which is detected at the fiber end, reflects these changes. U-shaped fiber optic sensors are very useful in chemical sensing, biomedical applications, and environmental monitoring because of their design, which makes it crucial to have great sensitivity for detecting minute physical or chemical changes[22].

A sensitive phototransistor capable of measuring small changes in light intensity as the solution interacts with the fiber. To record and quantify changes in light intensity, a photodetector a sensitive phototransistor was placed in place. These measurements which came about as a result of interactions between the fiber and the solution provided the information required to analyze the concentration of sugar. The cladder was removed sensor core increased the fiber sensitivity to the presence of sugar. Every time the fiber came into contact with sugar molecules, this FOS core sensing part changed its optical characteristics, intensifying the variations in light transmission and improving the sensor's ability to identify sugar in liquid samples[23], [24]. With the help of Fig. 2 changes in the input light source green LED light to change in output use phototransistor as photodetector output in voltage [25]. The absorption of light and reflection of propagating light change upon on jaggery concentration level[26].**2.2** Sample of jaggery samples were dissolved in distilled water to create a homogeneous solution. A standard jaggery solution was prepared for calibration, while additional samples contained known quantities of refined sugar (0.5% to 100% by weight). In this sample concentration 20ml/2g standard jaggery sample and mix ratio jaggery: sugar are 20ml/2gm between only 20ml/2g sugar concentration prepared for analysis[27]. Calibration procedure to establish the baseline light transmission, the sensor was first calibrated using common jaggery solutions. Calibration curves were then produced by testing solutions with different concentrations of refined sugar[28]. The phototransistor's measurements of variations in light intensity were the parameters that were assessed[29].

Data Collection and Analysis

Reliability was ensured by collecting data from multiple trials. The sensor's reaction to different amounts of refined sugar was investigated using a 20ml/2gm concentration ratio. The sensitivity, accuracy, and repeatability of the sensor were evaluated by statistical analysis, and the output was measured in millivolts.

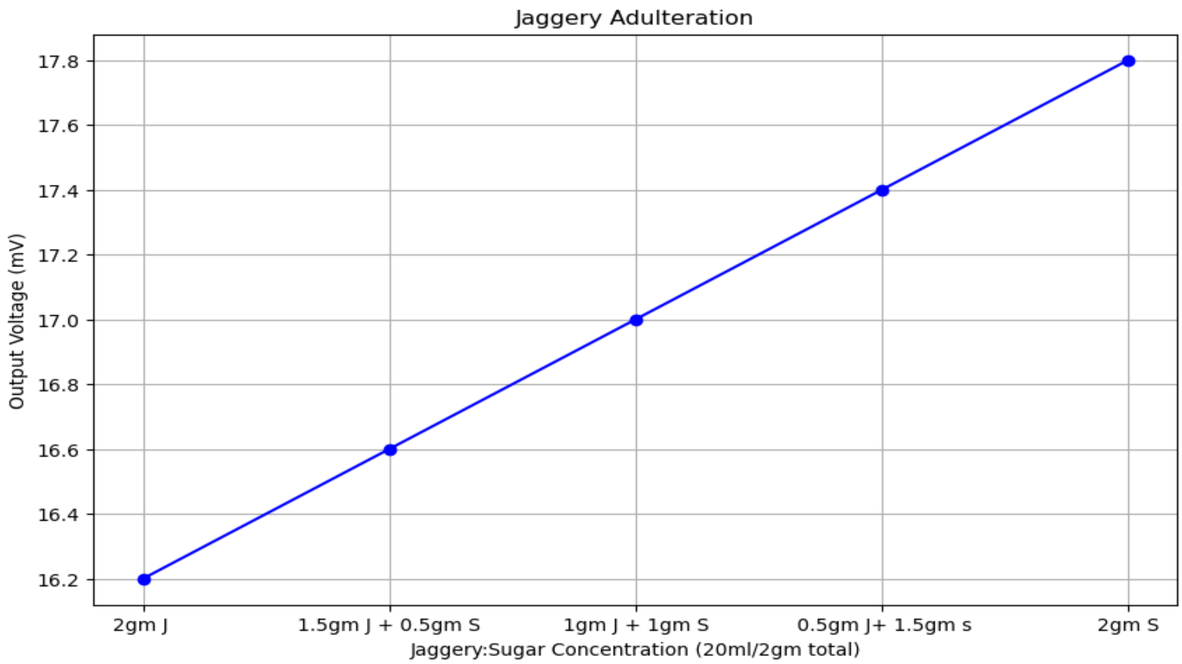

Fig. 3 Variation of the output signal with different ratios of the concentration of jaggery

III. RESULT

Calibration curves demonstrated a linear relationship between the light intensity decrease and the increase in refined sugar concentration in the liquid jaggery solution. The sensor's sensitivity was highest at a wavelength of 570 nm, where sugar molecules exhibited maximum interaction with the fiber coating. Accuracy and detection limits of the sensor successfully detected refined sugar concentrations as low as 25% in the jaggery solution. The accuracy of the sensor was found to be 94% when compared to chromatographic analysis. Detection limits were established at 0.3% for sugar impurities, indicating high sensitivity. Comparative analysis with conventional methods time efficiency chromatography takes 30 to 45 minutes to generate results, whereas the fiber optic sensor did it in less than 10 seconds. Cost-effectiveness it was far less expensive to set up the sensor than chromatographic equipment. Repeatability of the fiber optic sensor-generated data that was essentially consistent over 50 attempts.

IV. DISCUSSION

Analysis of findings of the intrinsic fiber optic sensor demonstrated excellent potential for detecting sugar adulteration in jaggery. The destructive testing approach in a liquid format improved measurement consistency, making it easier to standardize the process. The sensor's rapid response and ease of use make it suitable for onsite and real-time quality control. Advantages of conventional methods of the key advantages of the fiber optic sensor include invasive, it requires minimum sample preparation, time, and real-time monitoring capabilities. Unlike conventional techniques, which may require expensive chemicals and equipment, this sensor offers a cost-effective solution with comparable accuracy. Limitations and challenges although the sensor performed well in controlled laboratory settings, its application in field conditions requires further investigation. Additionally, the effect of other impurities (like moisture content or ash content in jaggery) on sensor readings needs to be evaluated to ensure specificity. Future studies should focus on field testing under varying environmental conditions. Integration with wireless communication for remote monitoring.

V. CONCLUSION

This research demonstrates the feasibility of using an intrinsic fiber optic sensor for the detection of refined sugar adulteration in jaggery through destructive testing in a liquid format. The sensor offers a quick, reliable, and cost-effective alternative to conventional detection methods. The promising results open up possibilities for broader applications in the food industry, potentially enhancing food safety and quality standards.

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