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SMART DAIRY TECH: REAL-TIME SENSING AND PRECISE CONTROL OF STEROID LEVELS IN MILK FOR ENHANCED QUALITY AND CONSUMER SAFETY

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ABSTRACT
This research introduces an innovative technology—a portable device utilizing advanced near-infrared (NIR) spectroscopy—to address the rising concern of steroids in milk. With cutting-edge sensors and algorithms, the device enables real-time, non-invasive analysis, ensuring precise control and monitoring of steroid concentrations. Its user-friendly design allows on-site testing, triggering immediate alerts for proactive intervention and maintaining product integrity. Integration with an automated control system establishes a feedback loop for dynamic adjustments, regulating steroid levels within approved limits. Validation tests showcase the device's reliability and robustness under diverse industry scenarios. Economic feasibility considerations emphasize potential benefits in production costs and consumer trust. This research contributes to food safety by offering a technology-driven solution for steroid contamination in milk, elevating industry standards and safeguarding public health through meticulous monitoring.

Keywords: Steroid Levels, NIR Spectroscopy, Portable Device, Automated Control System

Milk Quality, Sensor, Technology

INTRODUCTION:
Milk has long been recognized as a nutritional cornerstone, providing essential nutrients for human growth and development. The global dairy industry caters to a vast and diverse consumer base, emphasizing the significance of ensuring milk quality and safety. One recurring concern that has emerged in recent years is the presence of steroids in milk and its potential impact on consumer health. Steroids, though naturally occurring in cattle, have garnered attention due to their potential adverse effects when consumed in excessive amounts.

Steroids, a class of organic compounds with diverse biological functions, play a pivotal role in various physiological processes within mammals. However, the inadvertent introduction of steroids into the human diet through milk consumption has raised questions about their safety, prompting regulatory bodies to set strict limits on their presence in dairy products. Beyond regulatory implications, the detection and control of steroid levels in milk are essential for preserving product quality and consumer confidence in the dairy industry.

Traditional methods of monitoring steroid levels in milk often involve time-consuming laboratory analyses that are neither cost-effective nor conducive to real-time quality control. Therefore, there is an increasing need for innovative technologies that can provide rapid, accurate, and non-invasive measurements of steroid concentrations in milk.

This research paper presents a ground breaking approach aimed at addressing the challenge of steroid detection and control in milk. We introduce a novel device that harnesses advanced spectroscopic techniques, with a particular emphasis on near-infrared (NIR) spectroscopy, to enable non-destructive and real-time analysis of milk samples. The device employs state-of-the-art sensors and intelligent algorithms to precisely quantify a wide range of steroids with exceptional sensitivity and specificity.

The primary objective of this research is to design and develop a practical, user-friendly device that can be easily integrated into dairy farms and milk processing facilities. By providing dairy stakeholders with a reliable and rapid means of detecting steroid levels, the device empowers them to take timely corrective actions when necessary, ensuring that milk products meet rigorous quality standards and comply with regulatory requirements.

Moreover, our research delves into the critical aspect of controlling steroid concentrations in milk. We explore the incorporation of an automated feedback loop, connecting the sensing device with the milk production process. This integration enables dynamic adjustments in cattle health protocols, feed compositions, and other influential factors to maintain steroid levels within approved limits, ensuring optimal milk quality throughout the supply chain.

In the following sections, we present the experimental methodology, validation tests, and results that demonstrate the efficacy and performance of our proposed device. Additionally, we discuss the potential economic benefits of adopting this innovative technology and its implications for the dairy industry's commitment to consumer safety and public health.

In conclusion, the development of a reliable and efficient device for sensing and controlling steroid levels in milk holds immense promise for elevating milk quality management practices. By providing dairy farmers and processors with a cutting-edge solution, our research aims to strengthen consumer trust in dairy products while safeguarding public health against the risks associated with steroid consumption through milk. Ultimately, the integration of advanced technologies into the dairy sector has the potential to redefine industry standards and fortify the foundation of a safe and sustainable dairy industry.

LITERATURE SURVEY:

P. S. Venkateswaran et al., proposed a low-cost, durable, and simple optofluidic microviscometer based on the flow of two immiscible fluids in a microchannel, following the Hagen-Poiseuille flow equation [1]. The device accurately measures various adulterants' ratios (1% to 10%) in 60 milk samples, showing promise as an effective tool for combating milk adulteration with a high accuracy of 0.95. If successfully developed, this technology could have significant implications in ensuring milk quality and food safety in developing nations.

L. d. S. Ribeiro et al., introduces a hardware platform based on NIR diffuse reflectance spectroscopy to detect water adulteration in milk effectively [2]. Unlike the conventional cryoscope, this technology overcomes challenges posed by other adulterants like urea. The platform utilizes an optical condenser system with fixed lenses to enhance the signal-to-noise ratio, along with specific LEDs as light sources and InGaAsSb sensors with high sensitivity to the NIR spectrum. Testing on water-adulterated milk samples yielded highly accurate results with coefficients of determination exceeding 0.99. Further research is needed to explore the system's response to other variables and different types of adulterants, but if successful, this technology could become a valuable tool in combating milk adulteration and ensuring milk product quality and safety.

Malekinejad H & Rezabakhsh proposed a study on re-evaluation of hormone content in dairy products, focusing on estrogens [3]. It summarized physiological hormone concentrations and discussed their functions, biosynthesis, and metabolism pathways. Steroid hormones, especially estrogens, were of particular concern due to potential associations with breast and prostate cancers, based on epidemiological evidence.The research emphasized that even low doses of steroid hormones in dairy foods can have significant biological effects on both animals and humans. Previous knowledge focused on higher hormone concentrations, but recent findings suggest the need to consider the impact of even small amounts, especially during critical periods like perinatal and pubertal stages. With advancements in analytical methods and bioassays, understanding the potential effects of hormones, particularly estrogens, in dairy products on consumers' health becomes crucial. The study highlights the importance of further investigation to clarify possible risks, especially concerning meat from estrogen-treated animals, which may have implications for human health.

Tomaž Snoj & Gregor Majdič reviewed the growing concern about the potential effects of xenoestrogens on human health, particularly male reproductive health [4]. Cow's milk has been suggested as a possible source of these xenoestrogens, raising concerns about its impact on human well-being. Despite the numerous health benefits of milk, including its potential role in reducing certain cancers, questions have been raised about the estrogen levels in cow's milk.

Intensive farming practices, with extended milking periods during the cow's pregnancy when estrogen levels rise, have led to higher estrogen concentrations in milk. Studies have explored the potential effects of milk on reproductive health and endocrine-related cancers, both in laboratory animals and human epidemiological studies. This review article summarizes recently published literature on estrogen content in cow's milk and its potential health effects, specifically on the human reproductive system. While findings from various studies are not entirely consistent, the overall evidence suggests that the levels of estrogens in cow's milk are likely too low to cause significant health effects in humans.

Abedi AS et al., analysed lead (Pb) and cadmium (Cd) concentrations in cow milk from various regions of Iran and perform a meta-analysis on 1874 samples from 17 reports [5]. The results showed that Pb and Cd levels in milk were below WHO/FAO and national standards.Assessing the risks for adults and children, the estimated weekly intake (EWI) values were within safe limits set by JECFA, indicating no non-carcinogenic risk to consumers. However, the study found a potential carcinogenic risk associated with Pb consumption through milk, urging the need for reducing toxic metal levels in milk, especially in industrial regions of Iran, through planning and policy-making for consumer safety.

Soumia Belouafa et al., determined the reliability of measurement results and whether they can be confidently accepted or rejected due to inaccuracies. Statistical tools are essential to assess the suitability of analysis methods and establish trust in newly developed techniques. The study follows a common methodology inspired by regulatory guidelines for statistical data analysis in analytical method validation, optimizing the number of assays and meeting validation criteria [6]. Practical examples of quantifying pharmaceutical ingredients, heavy metals in fishery products, and drugs in seizures are provided to enhance understanding of statistical analysis of raw data.

Phillips, L & Moya, J standardized human exposure factors, resulting in various resources available to the scientific community. The US EPA developed the Exposure Factors Handbook to ensure consistency in exposure assessments, while other countries like the European Union, Australia, Canada, Japan, Korea, and Taiwan have also compiled exposure factors data for their populations [7]. This paper provides an overview of these resources, compares the US EPA handbook with international ones, identifies data gaps, and discusses ways to promote consistency among them.

Lucy MC proposed a paper about stress impacts on cattle productivity and fertility differently, as individuals experience varying strain levels even under the same stressors [8]. Environmental, disease, production, nutritional, and psychological stresses are typical for cattle. Stress affects the reproductive system through factors like body temperature, metabolic hormones, and the HPG and HPA axes. Strain from stress can influence uterine health, oocyte quality, ovarian function, and conceptus development. Cattle with lower strain in response to stress show higher fertility. Future management and genetic selection aim to reduce production stress, manage remaining strain, and select cattle with minimal stress response for improved fertility in farm animals.

Hernández-Castellano et al., reviewed the drawbacks in dairy production for major dairy species in the tropics, including cattle, water buffalo, sheep, goat, and camel. It also discusses future trends in research and development, reproduction and production systems, health issues, and environmental concerns, with a focus on greenhouse gas emissions. Addressing these challenges is crucial for sustainable and successful dairy production in tropical regions to meet the increasing demand for food.

PROPOSED WORK:

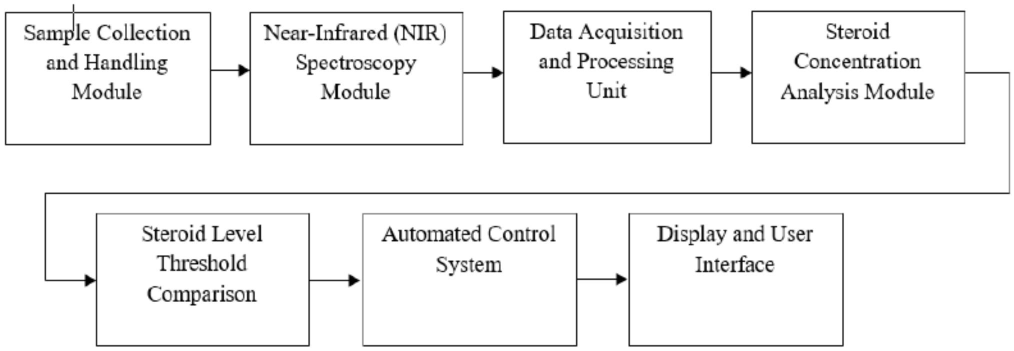

Fig.1 Block Diagram Device for the proposed system

The proposed device for sensing and controlling steroid levels in milk is a sophisticated system that combines advanced spectroscopic techniques with an automated feedback loop. The primary components of the device are as follows:

Sample Collection and Handling Module: This module is responsible for collecting milk samples from the dairy farm or milk processing facility. It ensures proper handling and preparation of the samples to maintain their integrity throughout the analysis process.

Near-Infrared (NIR) Spectroscopy Module: The heart of the device lies in the NIR spectroscopy module. It consists of a light source emitting near-infrared radiation and a spectrometer to measure the light's interaction with the milk sample. The NIR light interacts with the molecular bonds in the sample, providing a unique spectral fingerprint that reflects the chemical composition, including steroid concentrations.

Data Acquisition and Processing Unit: The data acquisition unit captures the spectral information obtained from the NIR spectroscopy module. This raw data is then processed by sophisticated algorithms to extract the specific features related to steroid levels in the milk.

Steroid Concentration Analysis Module: The processed data is fed into the steroid concentration analysis module, where machine learning algorithms or chemometric models are applied. These models are trained using a dataset of known milk samples with verified steroid levels. The analysis module quantifies the concentrations of different steroids in the milk sample.

Steroid Level Threshold Comparison: The detected steroid concentrations are then compared with predetermined threshold values for each steroid, adhering to regulatory standards. If the steroid levels are within the acceptable range, the device proceeds to the control phase. Otherwise, an alert is generated to signal the presence of undesirable steroid levels in the milk.

Automated Control System: The automated control system is an integral part of the device, connecting it to the milk production process. Based on the analysis results, the system takes corrective actions to regulate steroid levels in the milk. This could involve adjusting cattle feed compositions, health protocols, or other influencing factors to maintain the desired steroid levels.

Display and User Interface: The device incorporates a user-friendly display and interface, providing real-time monitoring of the analysis process, steroid concentrations, and control actions. Dairy farmers and processors can easily interact with the device and access critical information.

Working of the Device: Milk samples are collected and prepared for analysis using the sample collection and handling module. The NIR spectroscopy module illuminates the milk samples with near-infrared light, measuring the absorbance or reflectance of the light by the milk molecules. The data acquisition and processing unit processes the raw spectral data, preparing it for the steroid concentration analysis. The data is analyzed using machine learning algorithms trained to recognize the spectral patterns of different steroids. The module then calculates the concentrations of various steroids in the milk. The detected steroid concentrations are compared with pre-established threshold values for each steroid, determining if they comply with regulatory standards. If the steroid levels are within the acceptable range, the automated control system ensures no further actions are needed. However, if undesirable steroid levels are detected, the system triggers control actions. The automated control system adjusts relevant parameters in the milk production process to regulate steroid levels. This may involve modifying feed compositions, cattle health protocols, or other factors to maintain optimal steroid concentrations. Throughout the process, the user interface displays real-time data, analysis results, and control actions, enabling dairy farmers and processors to monitor and interact with the device effectively.

The integration of near-infrared spectroscopy, advanced data processing, and an automated control system empowers the device to provide real-time, non-invasive, and precise sensing and control of steroid levels in milk. This innovative approach ensures milk quality and consumer safety, enabling dairy stakeholders to maintain regulatory compliance and consumer confidence in their products.

The steroid concentration analysis in milk is an essential aspect of ensuring milk quality and safety. Steroids in milk can be natural hormones produced by the cow's body or synthetic steroids resulting from external factors. Some steroids, such as progesterone and estrogen, are naturally present in cow's milk.

To perform steroid concentration analysis for milk, the following steps are typically followed:

1. Sample collection: Representative samples of milk are collected from various sources or batches. Care is taken to handle the samples properly to avoid contamination and degradation.

2. Sample preparation: Before analysis, the milk samples need to be properly prepared. This usually involves homogenizing the samples to ensure a uniform distribution of steroids and removing any potential fat layer.

3. Extraction: Steroids in milk are present at low concentrations, so they need to be extracted from the milk matrix for accurate analysis. Commonly used methods include liquid-liquid extraction or solid-phase extraction.

4. Chromatography: Gas chromatography (GC) or high-performance liquid chromatography (HPLC) is widely employed to separate and quantify steroids in milk. These methods allow accurate measurements of individual steroids.

5. Detection and quantification: Chromatography is coupled with various detectors, such as mass spectrometry (MS), UV, or fluorescence, enabling the identification and quantification of specific steroids.

6. Calibration: A calibration curve is developed using standard solutions with known concentrations of the steroids of interest. This curve helps correlate the measured signal to the actual concentrations in the milk samples.

7. Data analysis: The data obtained from the chromatographic analysis is processed, and the concentrations of steroids in the milk samples are calculated.

8. Quality control: Rigorous quality control measures are implemented to ensure the accuracy and reliability of the analysis. This includes running blanks, duplicates, and spiking samples with known amounts of steroids to assess the precision and accuracy of the method.

9. Interpretation: The results are interpreted based on regulatory guidelines, industry standards, or specific research objectives.

It's important to note that steroid analysis in milk requires sophisticated laboratory equipment and trained personnel to perform the analysis accurately and reliably. The purpose of the analysis can vary, ranging from ensuring milk quality for human consumption to monitoring any potential illegal use of synthetic steroids in dairy cattle. Additionally, local regulations and testing requirements might dictate the specific methods and detection limits needed for steroid concentration analysis in milk.

PROPOSED SYSTEM:

Block diagram of the proposed system is given below. The system encloses the accurate measurement of steroids with machine learning algorithms and with hardware dependencies.

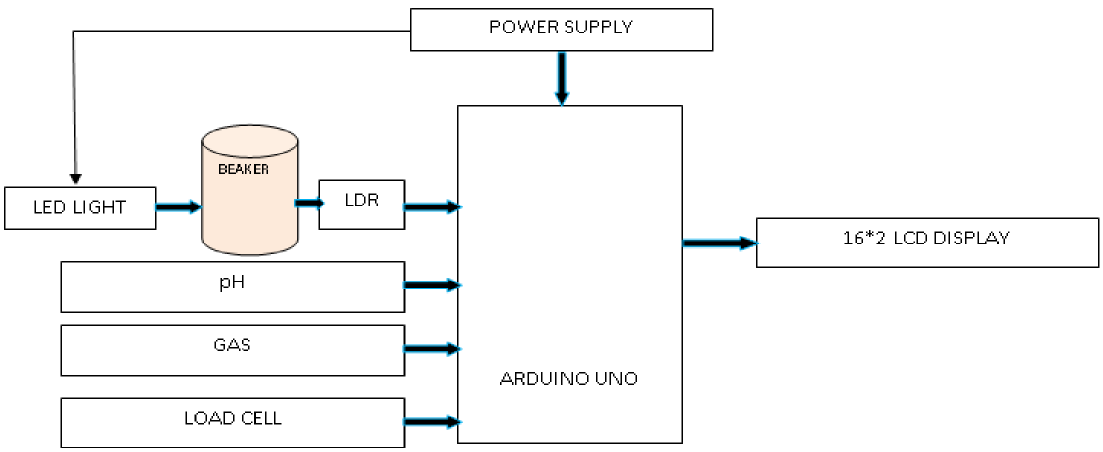

Fig.1 Block diagram of proposed system

The sensors and devices are interconnected, it being used to measure the milk quality and undergoes the validating process. There are three steps to ensure that the milk is in correct measurement. After the hardware interface the result will be displayed with the Matlab software, where we use machine learning algorithms to implement the data analytics part. The original part of graphical representation of the result will be carried out at the server depended software. This gives the exact reading of three stages of which examines the quality of milk with the comparison of given details in the coding section. The sensors which while working shows the exact output in the LCD which displays the pH level of the milk when kept contact with the product. Temperature sensor will examine the given temperature of the milk to ensure whether the milk is boiled or freshly provided. The Gas sensor is doing the important work of sensing the acids which are being inserted in the animal for boosting milk level. When a steroid (combination of chemicals) is inserted into an animal, the gas sensor senses the acids which are used and displays it in LCD. Color sensor is mainly used to check the thickness of the milk. Analysis is a predefined one which is already done at the backend of programming, according to the data used behind it checks for the chemicals used in the steroid and shows the output at the LCD. So, the thing which is implemented now is according to the chemicals used, it also displays the organ which is affected by the required steroid element. The pH value differs in such cases, according to which the organ will be affected, this value get varies from pH to pH. Such data are given at the back of programming in the dataset.

We give some criteria for steroid measurement in milk in this technique. As a result, every customer should be aware of this system. Milk is tested with a PH sensor, which is based on the density of the milk when it is poured into a beaker and illuminated by light. The LDR (Light Dependent Resistor) sensor will be used to detect Steroid in milk, and the parameter will be measured by its value. Then, using a load cell, we measure the cow's weight, and based on that weight, we recommend a steroid level to inject a cow. The gas sensors are utilized here to identify early microbial activity, rendering them ineffective for detecting adulteration of fruits and vegetables.

Experimental Results:

To validate the results, pH test conditions are given below in Table1.

Table 1: pH Test Conditions:

Condition	**pH value**
drinkable	6 < Ph <= 8
Non drinkable	Ph>8 or ph<=6

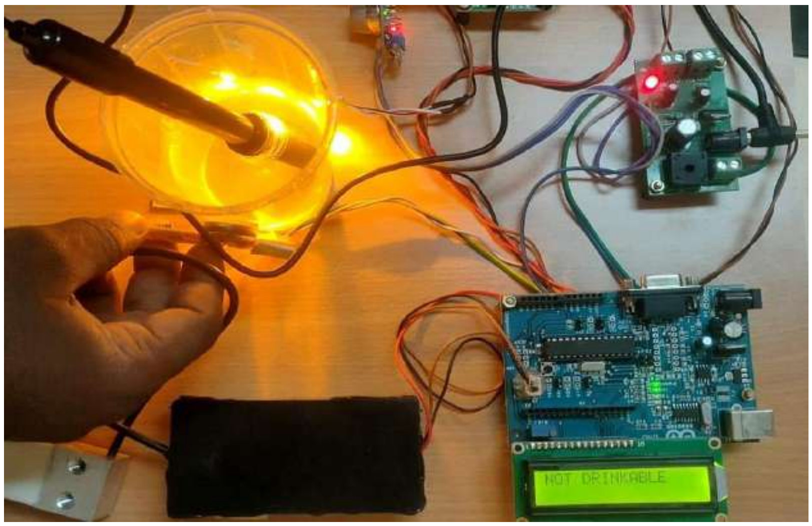

Fig. 2a Testing for pH value-Not drinkable

From Figure 2(a), it is observed that the sample contains steroid, controller is displaying that it is not suitable for drinking.

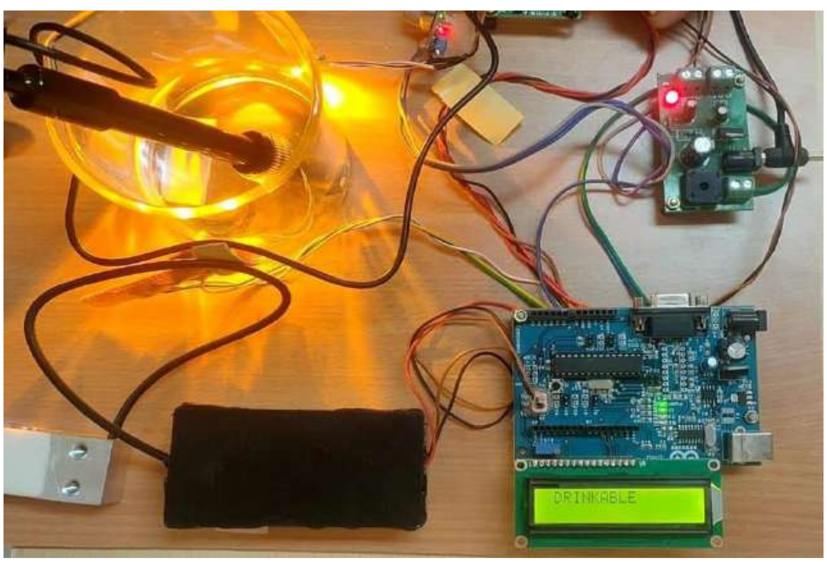

Fig.2b **testing for pH v**alue-drinkable

From Figure 2(b), it is observed that the sample does not contain steroid, controller is displaying that it is suitable for drinking.

LDR test conditions are given in Table 2 as follow.

Table 2: LDR Test Conditions

Condition	LDR values
Less fat content	LDR > 40
Medium fat content	25 < LDR < 40
More fat content	10 < LDR < 25

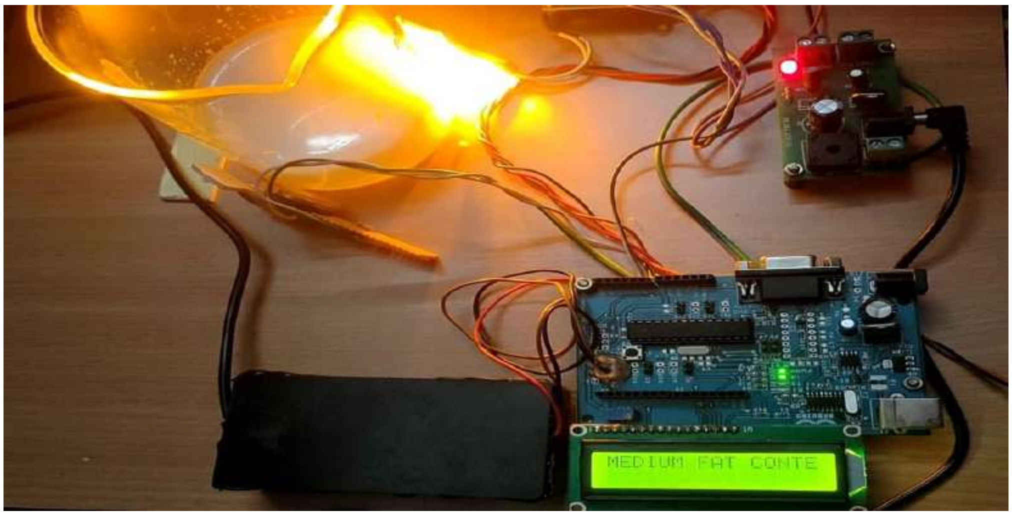

Fig.3a Testing for Fat content- medium fat content

From Figure 3(a), it is observed that the sample contain medium level fat which is decided by the controller based on LDR value.

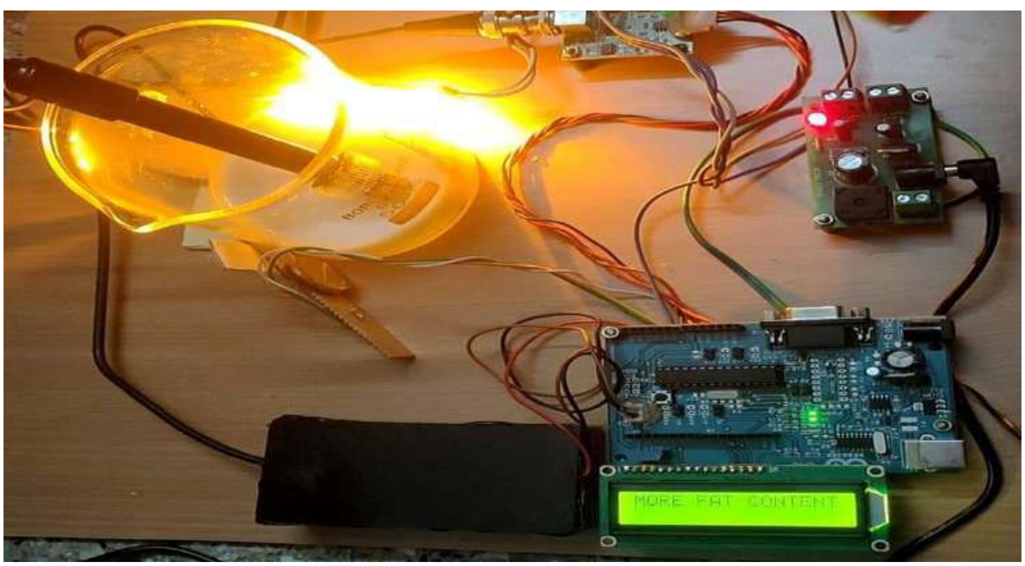

Fig.3b Testing for Fat content- more fat content

From Figure 3(b), it is observed that the sample contain High level fat which is decided by the controller based on LDR value.

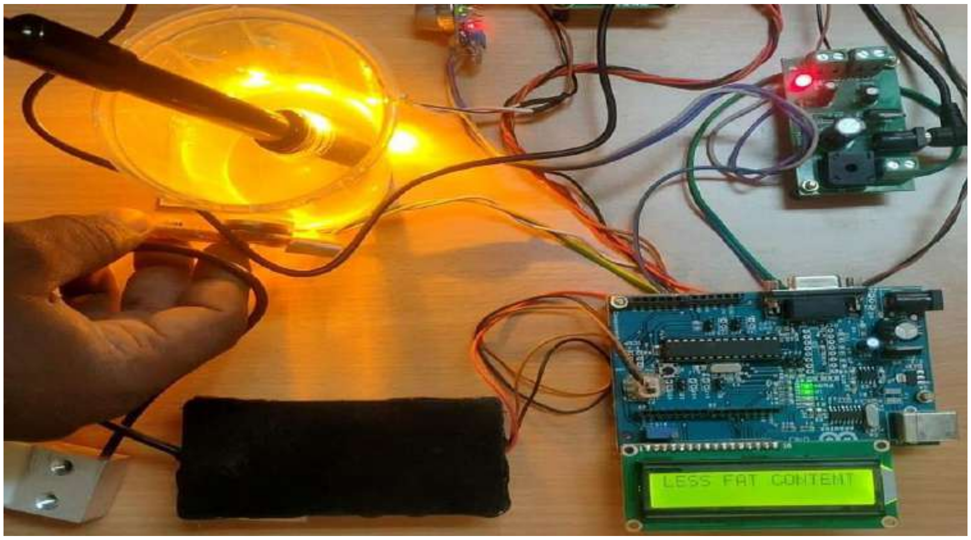

Fig.3C Testing for Fat content- more fat content

From Figure 3(C), it is observed that the sample contain Low level fat which is decided by the controller based on LDR value.

Load test conditions are given in Table 3 as follows.

Table 3: Load Test Condition

Condition	**Load values**
Adding 500ml steroid	1kg < load < 6kg
Adding 300ml steroid	6kg < load < 20kg

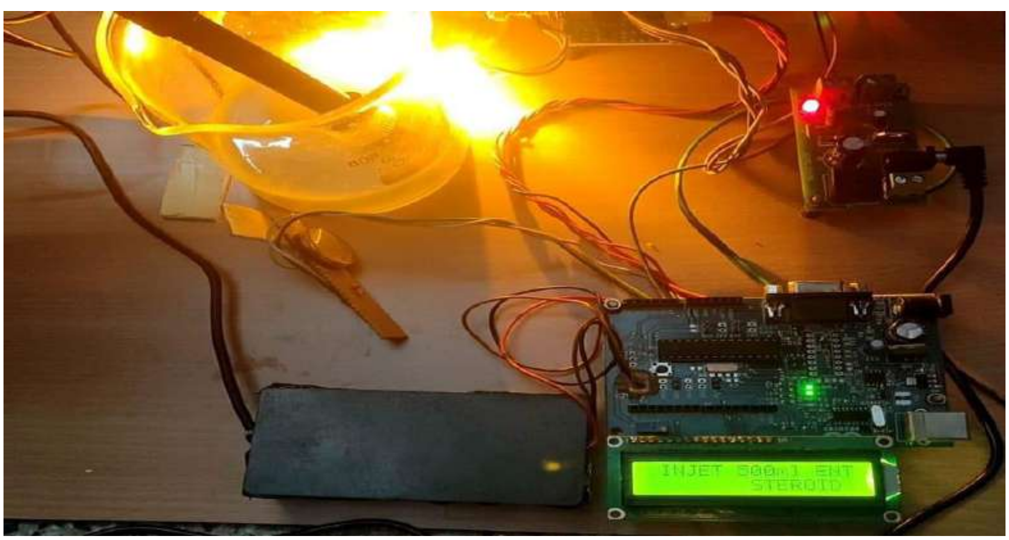

Fig 4(a): Load test condition-500 ml steroid injected

From Fig 4(a), it is observe that, proposed system is capable to find the amount of steroid content added. Here it is found to be 500 ml of steroid content added in the sample

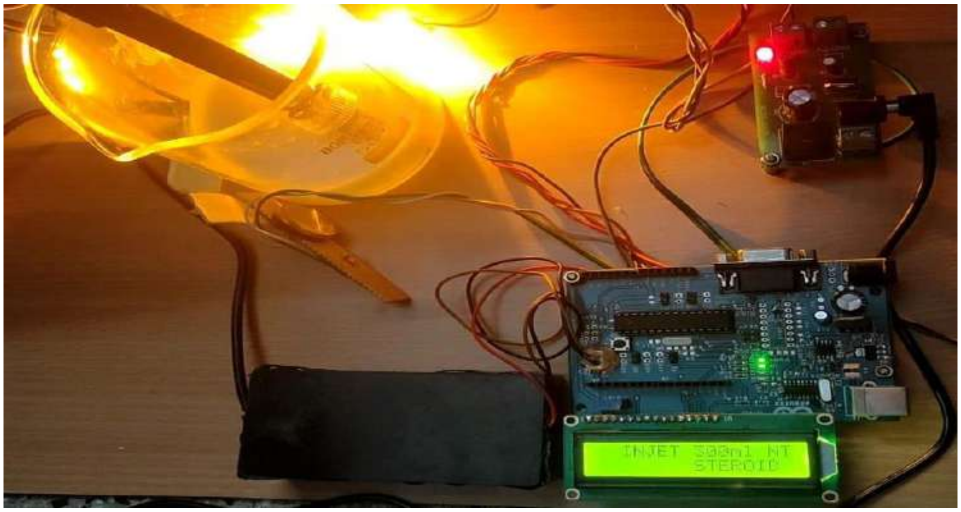

Fig 4(b): Load test condition-300 ml steroid injected

From Fig 4(b), it is observe that, proposed system is capable to find the amount of steroid content added. Here it is found to be 300 ml of steroid content added in the sample.

Gas sensor conditions are given in Table 4 as follows.

Table 4: Gas sensor condition

Condition	**Gas sensor values**
Non harmful	Gas <= 50
harmful	Gas > 50

From the table 4, it is observed that, if gas sensor output is less than or equal to 50, then sample is found to be non harmful. When gas sensor output is greater than 50, it is found to be harmful.

CONCLUSION:

In this study, we present a method for sensing and controlling steroid in milk that is both quicker and more precise. Microbial activity is measured in our system using a gas sensor, ph sensor and LDR sensor. The steroid of the milk is assessed by using a PH and LDR sensor of the milk. High-quality milk should contain no artificial steroid, hence the steroid of the milk is measured by using a PH sensor of the milk. This system measures milk collecting factors such as cow weight and milk FAT, and provides faster and more precise results than current systems, which are more expensive than the designed one. It is planned to incorporate IOT in the future.

REFERENCES:

1. P. S. Venkateswaran, A. Sharma, S. Dubey, A. Agarwal and S. Goel, "Rapid and Automated Measurement of Milk Adulteration Using a 3D Printed Optofluidic Microviscometer (OMV)," in IEEE Sensors Journal, vol. 16, no. 9, pp. 3000-3007, May1, 2016, doi: 10.1109/JSEN.2016.2527921.

2. L. d. S. Ribeiro, F. A. Gentilin, J. A. d. França, A. L. d. S. M. Felício and M. B. d. M. França, "Development of a Hardware Platform for Detection of Milk Adulteration Based on Near-Infrared Diffuse Reflection," in IEEE Transactions on Instrumentation and Measurement, vol. 65, no. 7, pp. 1698-1706, July 2016, doi: 10.1109/TIM.2016.2540946.

3. Malekinejad H, Rezabakhsh A. Hormones in Dairy Foods and Their Impact on Public Health - A Narrative Review Article. Iran J Public Health. 2015 Jun;44(6):742-58. PMID: 26258087; PMCID: PMC4524299.

4. Tomaž Snoj , Gregor Majdič, MECHANISMS IN ENDOCRINOLOGY: Estrogens in consumer milk: is there a risk to human reproductive health?, European Journal of Endocrinology, Volume 179, Issue 6, Dec 2018, Pages R275–R286, https://doi.org/10.1530/EJE-18-0591

5. Abedi AS, Nasseri E, Esfarjani F, Mohammadi-Nasrabadi F, Hashemi Moosavi M, Hoseini H. A systematic review and meta-analysis of lead and cadmium concentrations in cow milk in Iran and human health risk assessment. Environ Sci Pollut Res Int. 2020 Apr;27(10):10147-10159. doi: 10.1007/s11356-020-07989-w. Epub 2020 Feb 14. PMID: 32060829.

6. S. Belouafa, F. Habti, S. Benhar et al., “Statistical tools and approaches to validate analytical methods: methodology and practical examples,” International Journal of Metrology and Quality Engineering, vol. 9, 2017.

7. Mohan, A. and K,, S. 2023. Computational Technologies in Geopolymer Concrete by Partial Replacement of C&D Waste. International Journal of Intelligent Systems and Applications in Engineering. 11, 4s (Feb. 2023), 282–292.

8. L. J. Phillips and J. Moya, “Exposure factors resources: contrasting EPA’s Exposure Factors Handbook with international sources,” Journal of Exposure Science and Environmental Epidemiology, vol. 24, pp. 233–243, 2014.

9. M. C. Lucy, “Stress, strain, and pregnancy outcome in postpartum cows,” Animal Reproduction, vol. 16, pp. 455–464, 2019.

10. Mohan, A., Prabha, G. and V., A. 2023. Multi Sensor System and Automatic Shutters for Bridge- An Approach. International Journal of Intelligent Systems and Applications in Engineering. 11, 4s (Feb. 2023), 278–281.

11. Prabha , G. , Mohan, A. , Kumar, R.D. and Velrajkumar, G. 2023. Computational Analogies of Polyvinyl Alcohol Fibres Processed Intellgent Systems with Ferrocement Slabs. International Journal of Intelligent Systems and Applications in Engineering. 11, 4s (Feb. 2023), 313–321.

12. L. E. Hernandez-Castellano, J. E. Nally, J. Lindahl et al., “Dairy ´ science and health in the tropics: challenges and opportunities for the next decades,” Tropical Animal Health and Production, vol. 51, 2019.

13. Mohan, A., Dinesh Kumar, R. and J., S. 2023. Simulation for Modified Bitumen Incorporated with Crumb Rubber Waste for Flexible Pavement. International Journal of Intelligent Systems and Applications in Engineering. 11, 4s (Feb. 2023), 56–60.

14. T. Sato, S. Miyagawa, and T. Iguchi, “Subchapter 94G—estradiol-17β,” in Handbook of Hormones, Y. Takei, H. Ando, and K. Tsutsui, Eds., Academic Press, San Diego, CA, USA, 2016.