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E-Tongue for Rasa Identification of Ayurvedic Herbs

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Abstract- Ayurveda classifies medicinal herbs based on the concept of Rasa (taste), which plays a significant role in determining their therapeutic properties. Traditionally, Rasa identification is performed through human sensory perception, which is subjective, non-quantitative, and varies from person to person. To address this limitation, the present project proposes the design and development of a low-cost Electronic Tongue (E-Tongue) system for preliminary Rasa identification of Ayurvedic herbal extracts. The system integrates a pH sensor, Total Dissolved Solids (TDS) sensor, turbidity sensor, and temperature sensor interfaced with an ESP32 microcontroller. The measured physicochemical parameters are processed using rule-based logic to classify the probable Rasa category. A stepper motor mechanism is incorporated to automate sample handling, and the ESP32's built-in WiFi capability enables real-time monitoring through a web-based dashboard. The prototype was tested on selected herbal powders such as turmeric, neem, amla, and ginger, and distinct variations in sensor readings were observed corresponding to their expected taste characteristics. The developed system demonstrates an economical, portable, and objective approach to bridging traditional Ayurvedic knowledge with modern embedded and IoT technologies, providing a practical solution for academic research and preliminary herbal analysis.

Keywords: Automated bottle filling; Bottle capping; Bottle labeling; ESP32-CAM; OpenCV; Machine vision; STM32 microcontroller.

I. INTRODUCTION

Ayurveda is one of the oldest traditional systems of medicine, which mainly uses natural herbs and plant-based substances for treatment and prevention of diseases. A key concept in Ayurvedic pharmacology is Rasa, which refers to the taste of a substance and plays an important role in determining its therapeutic properties. According to Ayurveda, there are six types of Rasas: sweet, sour, salty, bitter, pungent, and astringent. These taste characteristics help in identifying the effect of herbs on the human body and are widely used by practitioners for diagnosis and treatment.

Traditionally, the identification of Rasa is performed through human sensory perception. However, this method is subjective and varies from person to person depending on individual sensitivity, experience, and environmental conditions. In addition, human tasting does not provide measurable or quantitative data, which makes it difficult to use in scientific analysis and standardization. Therefore, there is a need for a system that can provide objective, consistent, and measurable results for taste identification.

In recent years, Electronic Tongue (E-Tongue) systems have been developed to mimic the human taste sensing mechanism using sensor arrays and data processing techniques. These systems are widely used in food quality analysis, pharmaceutical applications, and liquid classification. However, most of the existing
E-Tongue systems are expensive, complex, and designed for laboratory use. This limits their application in small-scale research and educational purposes.

With the advancement of embedded systems and Internet of Things (IoT) technology, it is now possible to develop low-cost and portable sensing systems. Microcontrollers such as ESP32 provide built-in WiFi capability, high processing speed, and support for multiple sensors, making them suitable for real-time monitoring applications. By integrating different types of sensors, it is possible to measure physicochemical properties of liquids such as acidity, dissolved solids, and turbidity, which are indirectly related to taste.

In this paper, a low-cost Electronic Tongue system is proposed for preliminary Rasa identification of Ayurvedic herbal extracts. The system uses pH, Total Dissolved Solids (TDS), turbidity, and temperature sensors connected to an ESP32 microcontroller. The collected sensor data is processed using rule-based logic to classify the probable taste category. The system also includes a stepper motor mechanism for automated sample handling and a WiFi-based interface for real-time data monitoring.

The proposed system aims to provide a simple, economical, and effective solution for bridging traditional Ayurvedic knowledge with modern technology. It can be used for educational purposes, basic research, and preliminary analysis of herbal samples. The results obtained from the system demonstrate its capability to differentiate between different herbal extracts based on their measurable properties.

II. BACKGROUND

The concept of taste plays a significant role in both modern science and traditional medicine. In Ayurveda, taste, referred to as Rasa, is considered one of the fundamental properties of any medicinal substance. It is believed that the Rasa of a herb directly influences its therapeutic action in the human body. The six primary Rasas—sweet, sour, salty, bitter, pungent, and astringent—are associated with different physiological effects and are used to classify herbal medicines.

From a scientific perspective, taste perception is related to the chemical composition of substances. Different taste sensations are produced due to the presence of specific chemical compounds such as acids, salts, alkaloids, and other organic molecules. These compounds influence measurable parameters like pH, electrical conductivity, dissolved solids, and particle concentration. Therefore, it is possible to estimate taste characteristics indirectly by analyzing these physicochemical properties.

Electronic Tongue (E-Tongue) systems are designed to replicate human taste sensing using

sensor arrays and signal processing techniques. Instead of using biological taste receptors, these systems employ chemical and physical sensors that respond to different properties of liquid samples. The output signals from these sensors are processed to identify patterns that correspond to specific taste categories. This approach provides objective and repeatable results compared to traditional human-based evaluation.

In recent years, the development of low-cost sensors and microcontrollers has made it possible to design compact and portable E-Tongue systems. Sensors such as pH, Total Dissolved Solids (TDS), turbidity, and temperature sensors are widely available and can be easily interfaced with microcontrollers. These sensors measure important parameters that are indirectly related to taste perception. For example, pH indicates acidity or alkalinity, TDS represents the concentration of dissolved ions, and turbidity reflects the presence of suspended particles.

The ESP32 microcontroller has become a popular choice for embedded system applications due to its high processing capability, multiple input/output pins, and built-in WiFi functionality. It allows real-time data acquisition, processing, and wireless communication, making it suitable for IoT-based monitoring systems. By combining multiple sensors with ESP32, it is possible to develop an integrated system for liquid analysis and classification.

In this project, the background concepts of Ayurvedic Rasa theory and modern sensor-based analysis are combined to develop a simplified Electronic Tongue system. The system focuses on measuring key physicochemical parameters and using rule-based logic to estimate the taste category of herbal extracts. This approach provides a practical and cost-effective solution for preliminary analysis and demonstrates the potential of integrating traditional knowledge with modern technology.

III. LITERATURE SURVEY

Electronic Tongue (E-Tongue) systems have been widely studied for their ability to provide objective taste analysis using sensor arrays. Early work by Vlasov et al. [1] introduced the concept of multisensor systems for liquid analysis, demonstrating that taste perception can be represented through electrical signals and pattern recognition techniques. This study laid the foundation for further research in artificial taste sensing.

Legin et al. [2] explored the application of Electronic Tongue systems in pharmaceutical quality assessment. Their work highlighted the importance of objective taste evaluation, especially in identifying bitterness in drugs and improving formulation quality. Similarly, Di Natale et al. [3] proposed the integration of Electronic Nose and Electronic Tongue systems for food and pharmaceutical analysis, emphasizing the role of multiple sensors in improving classification accuracy.

Riul et al. [4] reviewed recent advancements in Electronic Tongue technology, including improvements in sensor materials and miniaturization. The study showed a shift from complex laboratory systems to more compact and portable designs. Peris and Escuder-Gilabert [5] further demonstrated the use of E-Tongue systems in detecting food adulteration and ensuring authenticity, proving that physicochemical parameters are strongly related to taste perception.

Wilson and Tattersall [6] discussed practical aspects such as calibration, sensor stability, and measurement accuracy, which are essential for reliable system performance. Their work emphasized that proper calibration techniques are necessary to obtain consistent results.

Chatterjee et al. [7] developed a low-cost Electronic Tongue system using embedded platforms for liquid classification. Their approach used simple logic instead of complex algorithms, making it suitable for educational and prototype-level applications. This concept is directly followed in the present work.

Kumar et al. [8] introduced IoT-based monitoring systems for real-time liquid analysis, showing the advantages of wireless data transmission and remote monitoring. This concept supports the use of ESP32 in the proposed system.

From the Ayurvedic perspective, Mishra and Jain [9] explained the importance of Rasa theory and its correlation with chemical properties of herbs. Their study provides a scientific basis for linking taste characteristics with measurable parameters such as pH and dissolved solids.

Although significant research has been done in Electronic Tongue systems, most existing solutions are expensive and designed for advanced laboratory use. There is a lack of low-cost, portable systems specifically designed for Ayurvedic applications.
The proposed project addresses this gap by developing a simple, sensor-based Electronic Tongue system using embedded and IoT technologies.

IV. PROJECT CHALLENGES AND FUTURE PLANS

Project Challenges
During the development of the proposed system, several challenges were encountered:

Sensor Calibration:
Accurate calibration of sensors was difficult, as small variations in readings could affect the final classification.

Indirect Measurement of Taste:
Taste is a complex property, and it cannot be measured directly. The system relies on indirect parameters, which may reduce accuracy.

Variation in Herbal Samples:
Different sample preparation methods and concentrations may lead to variation in sensor readings.

Limited Accuracy of Low-Cost Sensors: Affordable sensors have limited precision compared to industrial-grade equipment.

Environmental Factors:
Temperature and external conditions can affect sensor performance and stability.

Future Plans
The proposed system can be further improved in the following ways:

Machine Learning Integration:
Advanced algorithms can be used for more accurate classification.

Addition of More Sensors:
Including conductivity or chemical sensors can improve performance.

Mobile Application Development:
A smartphone interface can make the system more user-friendly.

Cloud Data Storage:
Storing data online can help in long-term analysis.

Improved Calibration Techniques:
Using standard laboratory methods can increase accuracy.

The future scope of this project is to develop a more accurate and industry-level system for herbal analysis.

V. PREPARATION OF THE PROJECT REPORT

The preparation of the project report was carried out in a systematic and structured manner to ensure clarity, accuracy, and proper documentation of the work. The report includes detailed information about the design, development, and testing of the Electronic Tongue system.

Initially, the problem statement and objectives of the project were defined based on the need for an objective method of Rasa identification. A detailed study of existing Electronic Tongue systems and Ayurvedic concepts was conducted through literature review. Based on this analysis, the system architecture and design were finalized.

The hardware components such as sensors, microcontroller, and motor driver were selected and assembled. The software was developed using Arduino IDE, and proper calibration of sensors was performed to obtain reliable readings. Experimental testing was carried out using selected herbal samples, and the observed data was recorded and analyzed.

The report was organized into different sections including introduction, background, literature survey, methodology, results, and conclusion. Proper formatting, diagrams, and tables were included to enhance readability. References were added based on standard citation formats to support the technical content. This structured approach ensured that the project report clearly explains the working, results, and significance of the proposed system.

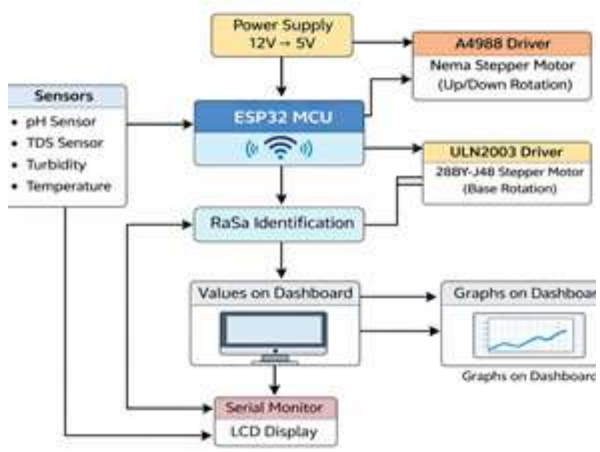


Fig. 1 Block Diagram

The block diagram represents the overall functional structure of the proposed Electronic Tongue system for Ayurvedic Rasa identification. The system mainly consists of a sensor array, ESP32 microcontroller, motor control unit, power supply, and IoT interface.

The sensor array includes pH, Total Dissolved Solids (TDS), turbidity, and temperature sensors, which are used to measure the physicochemical properties of herbal extracts. These sensors are connected to the analog and digital input pins of the ESP32 microcontroller.

The ESP32 acts as the central processing unit, where sensor data is collected, processed, and analyzed using predefined rule-based logic. Based on the processed data, the system classifies the Rasa category of the sample.

A stepper motor controlled through a driver circuit is used for automated sample positioning. The system is powered using a regulated DC supply to ensure stable operation. Additionally, the ESP32 provides WiFi connectivity, enabling real-time monitoring through a web-based interface. The working of the proposed system begins with the preparation of herbal samples in liquid form. Once the system is powered ON, the ESP32 initializes all connected sensors and establishes WiFi communication.

The stepper motor rotates the sample platform to position the selected sample for testing. The sensors are then used to measure parameters such as pH, TDS, turbidity, and temperature. These values are read by the ESP32 through its ADC channels.

The obtained sensor data is processed using rule-based logic implemented in the program. Based on predefined threshold values, the system determines the probable Rasa category of the herbal extract. The result, along with sensor readings, is displayed on a web dashboard. The process is repeated for multiple samples, ensuring automated and consistent operation.

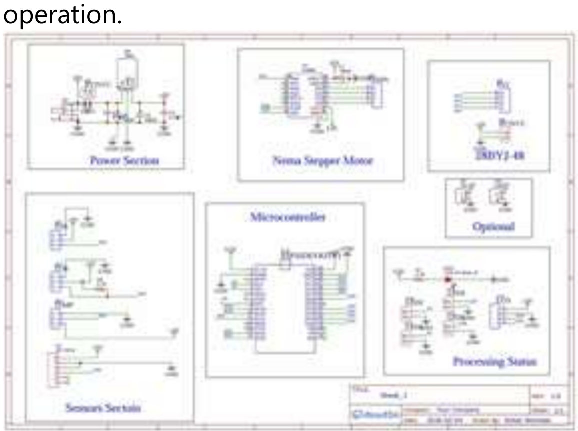


Fig. 2 Schematic Diagram

The schematic diagram illustrates the detailed electrical connections of the system components. The ESP32 microcontroller is interfaced with all sensors and the motor driver circuit.

The pH, TDS, and turbidity sensors are connected to the analog input pins of the ESP32, while the temperature sensor is connected through a digital communication pin. The ULN2003 driver circuit is used to interface the stepper motor with the microcontroller, ensuring proper current amplification.

A regulated power supply circuit is designed using a voltage regulator to provide a stable 5V output to all components. Proper grounding and filtering capacitors are used to reduce noise and ensure reliable operation.

The schematic design ensures safe and efficient communication between all hardware components.

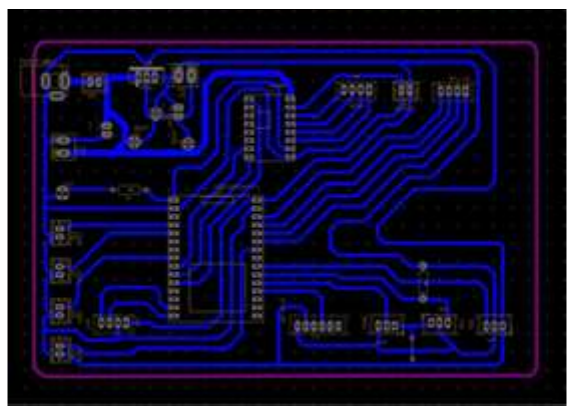


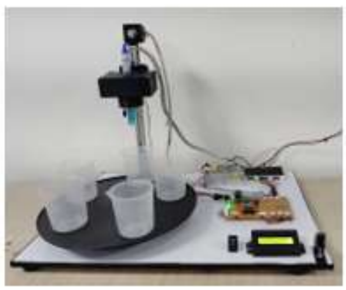
Fig. 3PCB of lAYOUT

The PCB layout is designed to provide a compact and organized arrangement of all components.
Proper routing techniques are used to minimize noise interference and ensure signal integrity.

Separate tracks are maintained for power and signal lines to avoid disturbances. The sensor connections are placed carefully to reduce signal loss, and adequate spacing is maintained between components for heat dissipation.

The PCB layout also ensures ease of assembly and maintenance, making the system more reliable and practical for real-world implementation.

VI. IMAGES OF PROJECT



VII. RESULT

The system was tested using selected Ayurvedic herbal samples such as turmeric, neem, amla, and ginger. The sensor readings obtained from these samples showed distinct variations in physicochemical parameters.

Amla exhibited lower pH values indicating acidic nature, while neem showed higher pH values corresponding to bitter characteristics. Ginger demonstrated moderate pH with higher turbidity, indicating pungent nature. Turmeric showed balanced readings representing mild bitterness.

The system was able to classify the samples based on predefined logic, demonstrating its capability for preliminary Rasa identification. Although the results are approximate, they show consistent differentiation between samples.

The performance of the system depends on proper calibration and sample preparation. The results validate the feasibility of using sensor-based approaches for taste analysis.

VIII. CONCLUSION AND FUTURE SCOPE

The proposed work presents the design and development of a low-cost Electronic Tongue system for preliminary Rasa identification of Ayurvedic herbal extracts using sensor-based analysis. By integrating pH, TDS, turbidity, and temperature sensors with an ESP32 microcontroller, the system provides an objective and measurable approach to analyze taste characteristics, which are traditionally identified through subjective human perception. The implementation of rule-based logic enables simple and effective classification, while IoT-based monitoring enhances usability through real-time data visualization.

The experimental results demonstrate that the system is capable of differentiating herbal samples based on their physicochemical properties, making it suitable for academic and basic research applications. Although the system provides approximate results, it establishes a strong foundation for further development. In future, the system can be improved by incorporating advanced techniques such as machine learning for more accurate classification, adding additional sensors for better analysis, integrating mobile and cloud-based platforms for data management, and enhancing calibration methods to achieve higher precision, thereby extending its application towards industrial and research-level herbal analysis systems.

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