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Auto Indoor Hydroponic Fodder Grow Chamber Using Solar Panel

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A B S T R A C T

The increasing demand for sustainable agriculture and efficient livestock management has created a need for innovative and resource-efficient fodder production techniques. Conventional fodder cultivation depends on fertile soil, favorable climatic conditions, extensive agricultural land, and adequate water resources, which are becoming increasingly limited due to urbanization, climate change, and water scarcity. To overcome these challenges, this paper proposes an Auto Indoor Hydroponic Fodder Grow Chamber, an automated soil-less cultivation system designed for the continuous production of fresh and nutritious green fodder.

The proposed system utilizes hydroponic technology to cultivate fodder crops such as maize, wheat, and barley under controlled indoor environmental conditions. An ESP8266 microcontroller serves as the central control unit, interfacing with sensors, water pumps, and LED grow lights to automate the cultivation process. Environmental parameters, including temperature, humidity, and water level, are continuously monitored to maintain suitable growing conditions. The automated water circulation mechanism ensures uniform moisture supply to the seeds, while artificial lighting supports plant growth in indoor environments. The system minimizes manual intervention through automatic control of essential cultivation operations and can be integrated with IoT-based platforms for remote monitoring and control. The proposed chamber aims to produce fresh green fodder within approximately seven days while reducing water consumption, land requirements, and labor compared to conventional cultivation methods. This system offers a sustainable, space-efficient, and cost-effective approach to modern livestock feed production, supporting year-round fodder availability and contributing to the development of smart agriculture.

Keywords: Hydroponics, ESP8266, Automated Fodder Production, Indoor Farming, IoT, Embedded Systems, Smart Agriculture, Sustainable Livestock Management.

I. Introduction

Agriculture plays a significant role in supporting the livestock industry by providing nutritious green fodder essential for maintaining animal health, improving milk production, and enhancing overall productivity. However, conventional fodder cultivation depends heavily on soil fertility, seasonal variations, rainfall, and the availability of agricultural land and water resources. These limitations often affect the continuous availability of quality animal feed, particularly in regions experiencing water scarcity and unpredictable climatic conditions. Therefore, adopting modern agricultural technologies is essential for improving fodder production and ensuring sustainable livestock management.

Hydroponics is an innovative soil-less cultivation technique in which plants are grown using water containing essential nutrients required for their development. This approach provides an alternative to conventional farming by reducing land requirements, optimizing water consumption, and enabling cultivation under controlled environmental conditions. Previous research has explored the development of hydroponic fodder grow chambers to improve the availability of fresh green fodder through controlled cultivation methods [1]. Further developments have focused on integrating IoT technologies into indoor hydroponic fodder systems to support automated operations and environmental monitoring [2].

Different hydroponic cultivation techniques, particularly the Nutrient Film Technique (NFT), have been investigated to improve nutrient circulation and automate the growing process using microcontroller-based systems [3]. The availability of affordable hydroponic technologies and chamber-based cultivation approaches has also encouraged the development of compact indoor farming solutions [4]. The fundamental principles of growing fodder without soil, using water supplemented with essential nutrients, have been discussed in earlier publications on hydroponic cultivation [5]. Similarly, the theoretical aspects of soilless culture, including plant growth requirements and nutrient management, provide an important foundation for designing efficient hydroponic systems [6].

Recent advancements in automation and mobile application technologies have further improved the accessibility and management of hydroponic farming. An automated hydroponic system based on mobile applications demonstrates the possibilities of monitoring and controlling cultivation activities remotely

[7]. IoT-based automated hydroponic systems have also been investigated to improve system monitoring, data communication, and the automatic regulation of environmental conditions [8]. In addition, smart greenhouse development has demonstrated how sensor networks and information technologies can be integrated to monitor and manage agricultural environments efficiently [9]. Industrial Internet of Things (IIoT) communication models have further highlighted the importance of connected technologies in supporting intelligent agricultural and agro-industrial applications [10].

Considering these technological developments, the proposed Auto Indoor Hydroponic Fodder Grow Chamber aims to develop an automated indoor cultivation system for producing fresh and nutritious green fodder. The system uses an ESP8266 microcontroller as its central processing unit to monitor environmental parameters and control essential operations. Sensors are incorporated to measure temperature, humidity, and water levels, while water pumps and LED grow lights are operated to maintain suitable conditions for plant growth. The water circulation mechanism provides the required moisture to the seeds, and artificial lighting supports cultivation inside the enclosed chamber.

The proposed system is designed to cultivate fodder crops such as maize, wheat, and barley within approximately seven days under suitable environmental conditions. Automation of water supply, lighting, and environmental monitoring helps minimize manual intervention and improve resource utilization. Furthermore, IoT integration provides the possibility of remote monitoring and control, making the system suitable for modern livestock farming applications.

The primary objective of this project is to design and implement a compact, economical, and automated hydroponic cultivation system that supports year-round green fodder production. By combining hydroponic technology, embedded systems, and IoT-based automation, the proposed system aims to reduce dependency on conventional agricultural resources and provide a sustainable solution for livestock feed production.

II. Problem Statements

Conventional fodder cultivation depends on fertile soil, favorable climatic conditions, sufficient agricultural land, and regular water availability. Seasonal variations, water scarcity, and increasing demand for livestock feed make it difficult for farmers to maintain a continuous supply of fresh and nutritious green fodder. Additionally, traditional cultivation methods require considerable manual effort for watering, monitoring, and maintaining suitable growing conditions, which can affect productivity and resource efficiency.

To overcome these challenges, the proposed Auto Indoor Hydroponic Fodder Grow Chamber aims to develop a compact and cost-effective automated system for indoor fodder cultivation without soil. The system utilizes an ESP8266 microcontroller, sensors, water pumps, and LED grow lights to monitor and control essential environmental parameters such as temperature, humidity, and water levels. The primary objective is to produce fresh green fodder within approximately seven days under suitable growing conditions while reducing water consumption, manual intervention, and dependency on seasonal climatic conditions

III. Proposed System

A. The System Design and Development

The proposed Auto Indoor Hydroponic Fodder Grow Chamber is designed to automate the cultivation of fresh green fodder using hydroponic technology in a controlled indoor environment. The system consists of an ESP8266 microcontroller, temperature and humidity sensors, water-level sensors, water pumps, LED grow lights, and a hydroponic growing chamber. The ESP8266 acts as the central control unit, receiving sensor data and controlling the water circulation and lighting operations based on predefined conditions. Seeds such as maize, wheat, and barley are placed in growing trays, where water is supplied periodically to maintain the required moisture for germination and growth. LED grow lights provide artificial illumination, while environmental parameters are continuously monitored to maintain suitable growing conditions. The system also supports IoT-based monitoring, enabling users to observe operating conditions remotely. The overall design aims to achieve efficient water utilization, reduced manual intervention, and continuous production of nutritious green fodder within approximately seven days.

B. Block diagram

The block diagram of the proposed Auto Indoor Hydroponic Fodder Grow Chamber illustrates the overall arrangement and interaction of the different hardware components used in the system. The ESP8266 microcontroller acts as the main processing unit, which receives input signals from the temperature and humidity sensor and water-level sensor to monitor the internal environmental conditions of the growing chamber. Based on the received sensor information and predefined control conditions, the microcontroller processes the data and generates appropriate control signals for operating the water pump and LED grow lights. A regulated power supply provides the necessary electrical power to the microcontroller & sensors.

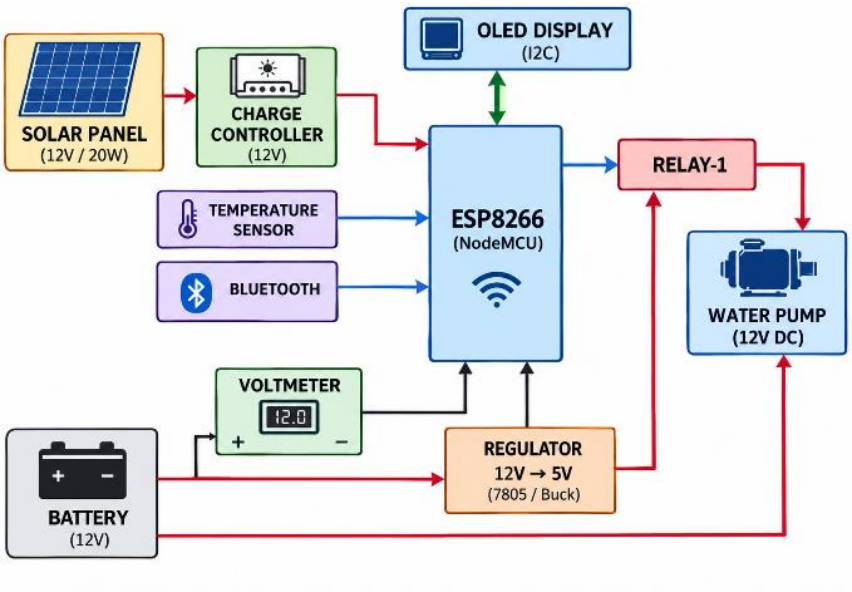


Figure 1: Block diagram of the proposed system

The output section consists of a water circulation mechanism and LED grow lights, which support the germination and development of fodder seeds such as maize, wheat, and barley. The water pump supplies water to the growing trays at predefined intervals, ensuring adequate moisture for seed growth, while the LED lighting system provides the illumination required for indoor cultivation. The ESP8266 also provides Wi-Fi connectivity, allowing the system to be connected to an IoT platform for remote monitoring of environmental parameters and system operation. The coordinated functioning of these components helps maintain suitable growing conditions, reduces manual involvement, and enables efficient production of fresh green fodder in a controlled environment.

Solar Panel and Power Management Unit: The proposed system incorporates a 12V, 20W solar panel to harness solar energy and provide a renewable power source for the water pumping operation. A solar charge controller is used to regulate the power generated by the solar panel and safely charge the 12V rechargeable battery, preventing overcharging and deep discharge. The battery stores the generated energy and supplies power to the system whenever solar energy is insufficient. A voltmeter is integrated to monitor the battery voltage and provide information about the available power. Furthermore, a voltage regulator (12V to 5V) converts the battery voltage into a stable 5V supply required for operating the ESP8266 microcontroller and other low-voltage electronic components.

Sensing, Control and Actuation Unit: The ESP8266 (NodeMCU) serves as the central processing and control unit of the proposed system. A temperature sensor measures the surrounding or monitored temperature and transmits the readings to the microcontroller for processing. Bluetooth communication enables wireless interaction and control of the system through a compatible device. An OLED display connected through the I2C interface provides real-time information, including temperature and system operating status. Based on the programmed control logic, the ESP8266 operates a relay module (Relay-1), which switches the 12V DC water pump ON or OFF according to the specified operating conditions or user commands. The integration of solar power, battery storage, sensing, wireless communication, and automated pump control improves energy utilization, monitoring capability, and overall system efficiency.

B. Circuit diagram

The proposed system consists of a solar-powered automated water pumping mechanism integrated with an ESP8266 (NodeMCU) microcontroller for intelligent monitoring and control. A 12V, 20W solar panel generates electrical energy, which is regulated through a solar charge controller to charge a 12V rechargeable battery. The stored energy supplies the system, while a DC-DC voltage regulator converts 12V into a stable 5V supply for the microcontroller and associated electronic components. A voltmeter continuously monitors the battery voltage, and a temperature sensor provides real-time temperature measurements to the ESP8266. An OLED display interfaced through the I2C protocol displays system parameters, including temperature and pump operating status, while Bluetooth communication enables wireless interaction with the system. Based on the programmed control logic and user commands, the ESP8266 activates or deactivates the relay module, which controls the operation of the 12V DC water pump. This integrated arrangement provides renewable energy utilization, real-time monitoring, and automated water pump control, thereby improving system convenience and energy efficiency.

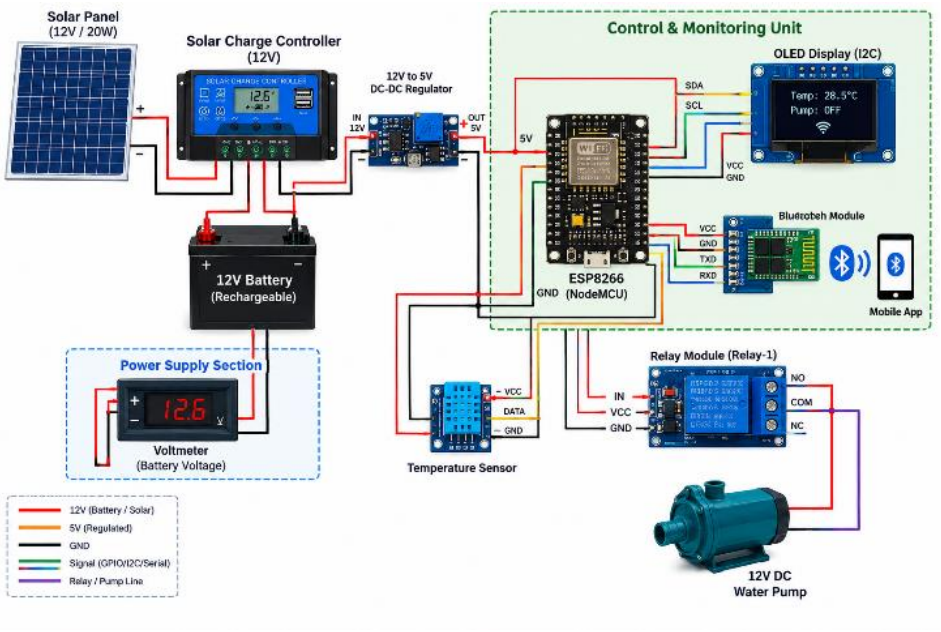


Figure 2: detailed circuit and hardware interconnection diagram of the proposed auto indoor hydroponic fodder grow chamber.

4. Result analysis

The developed Auto Indoor Hydroponic Fodder Grow Chamber consists of a compact mechanical structure fabricated using PVC pipes and green shade net material, providing a suitable enclosure for indoor fodder cultivation. Multiple growing trays are arranged inside the chamber to support the cultivation of seeds such as wheat and maize at different growth stages, as shown in Fig. 3(a). The controlling unit, illustrated in Fig. 3(b), integrates a NodeMCU ESP8266 microcontroller, relay module, Bluetooth communication module, rechargeable battery, and water pump to perform automated irrigation operations. The microcontroller controls the pump based on programmed timing and sensor inputs, thereby reducing manual intervention and improving water management.



Figure 3(a) : Mechanical structure



Figure 3(b) : Controlling Unit

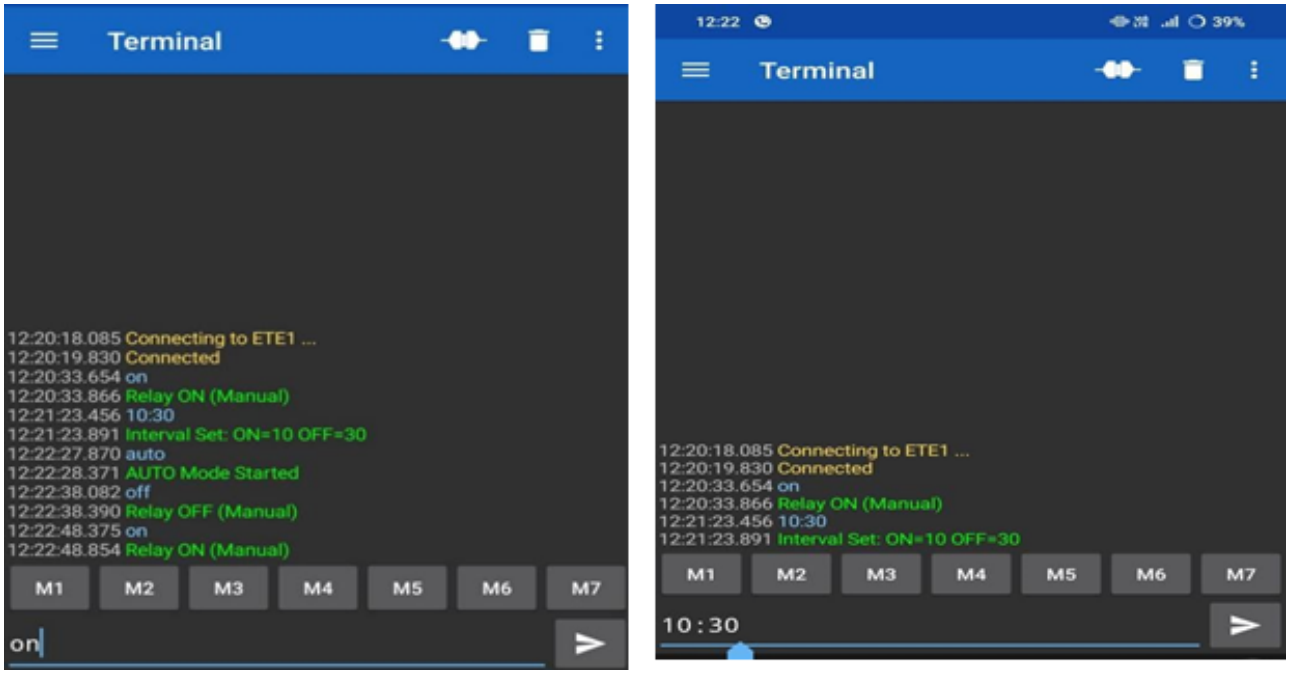


Figure 3(c) : Bluetooth Serial Terminal Log

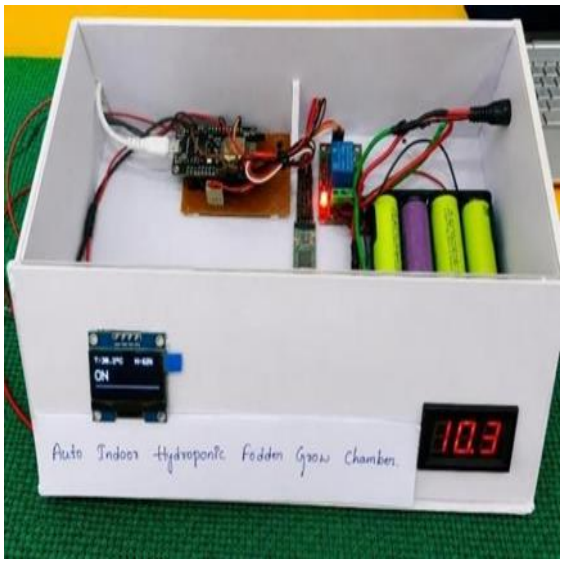


Figure 3(d) : Automated Microcontroller Setup

The mobile-based Bluetooth Serial Terminal, shown in Fig. 3(c), enables users to operate the system through manual commands such as ON and OFF, along with automatic mode selection. The terminal displays relay operation messages and supports predefined timing intervals for automated pump control. The physical prototype, presented in Fig. 3(d), demonstrates communication between the mobile application and the microcontroller, while the OLED display indicates the operating status and monitors temperature and humidity levels. The developed prototype demonstrates the practical application of embedded systems and automation in hydroponic fodder cultivation, providing a compact and economical approach to smart agriculture.

5. Conclusion and Future scope

The proposed Auto Indoor Hydroponic Fodder Grow Chamber demonstrates the integration of hydroponic technology, embedded systems, and automation for sustainable green fodder production. The developed prototype uses an ESP8266 microcontroller, sensors, relay module, water pump, and LED grow lights to support indoor cultivation under controlled conditions. Bluetooth-based communication enables manual and automatic operation of the irrigation system, while the OLED display provides information about the operating status and environmental parameters. The compact structure offers a practical and economical approach to fodder cultivation with reduced manual intervention and efficient resource utilization. In the future, the system can be enhanced by incorporating IoT-based remote monitoring, pH and electrical conductivity sensors, automatic nutrient mixing, AI-based environmental control, and solar power integration. Additional growing trays and cloud-based data management can also be implemented to improve

scalability and operational efficiency. These improvements can make the system more reliable and suitable for large-scale hydroponic fodder production, contributing to sustainable agriculture and smart livestock management.

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