

A Survey on Hydroponic Fodder Grow Chamber Using IoT

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Abstract: The severe degradation of natural pastures, increasing climate variability, and water scarcity are major challenges to sustainable livestock production. Green fodder is an essential nutritional input for dairy cattle, sheep, and goat farming. However, conventional soil-based fodder cultivation requires large land areas, high water consumption, and considerable labor, with a long growth cycle of approximately 45–60 days. Drought and seasonal variations further affect the continuous availability of fresh fodder. Hydroponic fodder production provides a promising alternative by growing nutritious green forage without soil under controlled environmental conditions. Sprouted grains can produce fresh green fodder within approximately seven days, while requiring less land and water than conventional cultivation. The integration of Internet of Things (IoT) technology can further improve system efficiency through automatic monitoring and control of temperature, humidity, water supply, and other environmental parameters. This paper presents a survey of IoT-enabled hydroponic fodder grow chambers, focusing on sensor integration, closed-loop microclimate regulation, automated misting systems, and remote telemetry using the NodeMCU ESP8266 microcontroller. The system provides a low-cost and efficient approach for continuous and sustainable green fodder production.

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I. INTRODUCTION

Livestock rearing is an important part of the rural economy and provides livelihood and income to farming communities. Green fodder is essential for maintaining animal health, growth, milk production, and reproductive performance. However, the availability of green fodder is affected by seasonal changes, increasing cultivation costs, water scarcity, and limited agricultural land.

Conventional fodder cultivation requires soil, irrigation water, fertilizers, and manual labor. It generally requires around 45–60 days for harvesting and is highly dependent on suitable climatic conditions. Drought, irregular rainfall, and increasing land requirements have further increased the difficulty of maintaining a continuous supply of fresh fodder.

Hydroponic fodder production offers an alternative method in which grains are grown without soil under controlled conditions. With proper water and environmental management, fresh sprouted fodder can be produced within approximately seven days. The method requires less land and can reduce water usage, making it suitable for areas facing resource limitations.

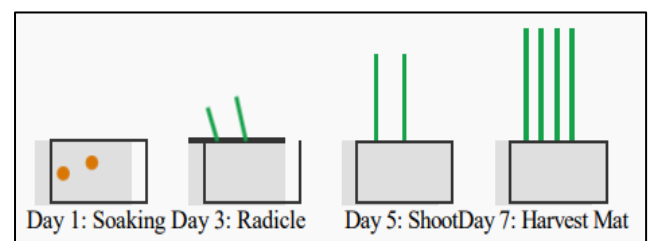


Fig 1 7-Day Hydroponic Fodder Physiological Growth Cycle.

As shown in Fig. 1, seed germination begins with water absorption, triggering cell division and radicle emergence by Day 3. By Day 5, photosynthetic leaves develop, forming an intertwined, edible root mat by Day 7.

➤ Need For IoT in Fodder Chambers

Manual fodder grow chambers suffer high failure rates due to environmental fluctuations. Overwatering promotes fungal pathogens such as *Pythium* and *Fusarium* (root rot), destroying entire tray yields within 24 hours [5]. Conversely, under-watering causes desiccation, causing embryonic shoot collapse.

Integrating Internet of Things (IoT) technologies replaces manual monitoring with precise, automated environmental regulation.

• **Key Operational Benefits Include:**

- ✓ Micro-misting control: Maintaining humidity at 65%-75% RH prevents desiccation without waterlogging.
- ✓ Temperature regulation: Keeping chamber temperatures between 18°C and 23°C optimizes enzymatic activity.
- ✓ Photoperiod automation: Providing 10-12 hours of LED light promotes chlorophyll synthesis.
- ✓ Remote telemetry: Transmitting sensor data to cloud platforms enables real-time mobile tracking and fault alerts.

• **IoT Architecture & Components**

An automated hydroponic fodder chamber relies on an integrated hardware-software framework that links field sensors, microcontrollers, actuating relays, and cloud analytics dashboards.

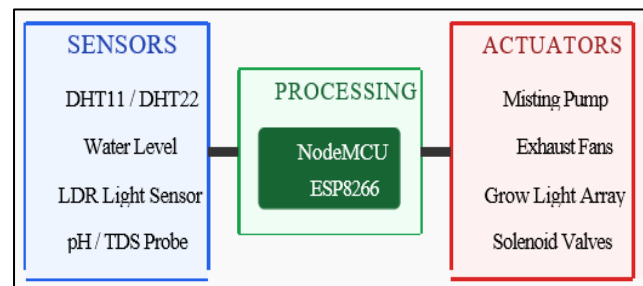


Fig. 2. Architectural Overview of the IoT Hydroponic Control System.

• **Nodemcu Esp8266 Microcontroller**

The NodeMCU ESP8266 serves as the primary system controller. It features an L106 32-bit RISC microprocessor running at 80 MHz, 128 KB of RAM, and 4 MB of flash storage [6]. Its integrated IEEE 802.11 b/g/n Wi-Fi stack enables direct cloud connectivity.

Table 1 Sensor Parameters and Operating Ranges

Sensor Module	Target Parameter	Operating Range	Optimal Value
DHT22 / AM2302	Chamber Temp & Humidity	-40-80°C / 0-100% RH	20°C / 70% RH
HC-SR04 Ultrasonic	Reservoir Water Level	2 cm – 400 cm	> 15 cm depth
LDR / TSL2561	Light PAR Intensity	0-40,000 Lux	2,500-3,000 Lux

• **Sensor Suite Specifications**

Precise closed-loop control relies on continuous data collection from environmental and liquid sensors placed throughout the grow chamber:

- ✓ DHT11/DHT22 Sensor: Measures ambient temperature (0 to 50°C ±0.5°C) and relative humidity (20 to 90% RH ±2%).
- ✓ Ultrasonic Level Sensor (HC-SR04): Measures water levels in the nutrient reservoir using 40 kHz ultrasonic pulses.
- ✓ Light Sensor (LDR / TSL2561): Monitors ambient illuminance (lux) to regulate supplementary LED grow lights.
- ✓ Analog pH Probe & Signal Board: Monitors solution acidity (pH 0-14). The ideal pH range for cereal sprouting is 6.0 to 6.8 [7].

• **Actuation and Switching Electronics**

The control signals from the ESP8266's 3.3V GPIO pins drive high-voltage AC/DC devices using an optocoupler-isolated 4-channel relay module.

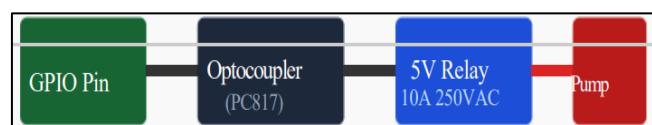


Fig 3 Optoisolated Relay Driver Schematic for AC Load Switching.

II. SYSTEM WORKING PRINCIPLE

The IoT hydroponic fodder chamber uses a closed-loop feedback design to maintain optimal environmental parameters. Sensor data is processed continuously, triggering

automated responses when conditions deviate from preset thresholds.

➤ **Vapor Pressure Deficit (VPD) Regulation**

Vapor Pressure Deficit (VPD) measures the difference between the pressure exerted by water vapor in saturated air and actual vapor pressure.

VPD directly drives transpiration rates in growing fodder crops [8]:

$$VP_{sat} = 0.61078 \times e^{(17.27 \times T) / (T + 237.3)} \text{ (kPa)} \quad VPD = VP_{sat} \times (1 - RH / 100) \text{ (kPa)}$$

Where T represents ambient chamber temperature in °C and RH is relative humidity percentage. The system dynamically targets a VPD range of 0.4 kPa to 0.8 kPa.

➤ **Automated Control & Remote Dashboards**

The system uses two communication protocols: local closed-loop control handles immediate relay operations, while MQTT over TCP/IP manages cloud telemetry.

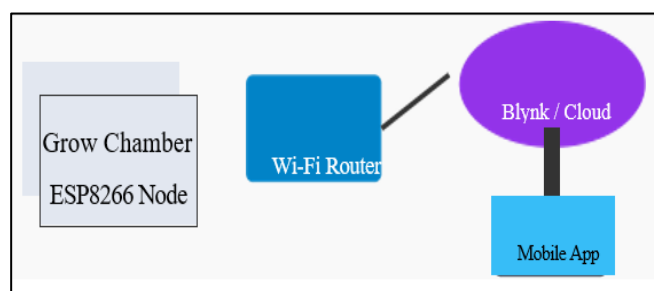


Fig 4 End-to-End Cloud Communication Network Topology.

III. LITERATURE REVIEW

Recent research highlights increasing adoption of controlled environment agriculture (CEA) using low-cost embedded hardware platforms [9]-[13].

Sharma et al. [9] developed an automated hydroponic fodder unit based on the Arduino Uno microcontroller. Their system used fixed timer schedules for misting, achieving consistent germination. However, the lack of responsive sensor integration resulted in excessive water consumption during humid periods.

Patil and Deshmukh [10] addressed these limitations by integrating DHT11 temperature-humidity sensors and soil moisture probes into an ESP8266 platform. Their dynamic thresholding algorithm reduced water consumption by 34% compared to fixed-timer systems.

Al-Kodmani [11] evaluated the nutritional value of hydroponic fodder, reporting significant increases in crude protein (from 11.2% in dry seed to 18.6% in 7-day sprouted fodder).

Kumar et al. [12] introduced an IoT framework using Raspberry Pi single-board computers for multispectral analysis of hydroponic crop canopy health.

Table 2 Comparative Evaluation of Fodder Production Methods

Evaluation Parameter	Traditional Field	Manual Chamber	IoT Chamber
Growth Cycle	45-60 Days	7-8 Days	7 Days (Optimized)
Water Use (L/kg)	70-100 L	8-12 L	1.5-3.0 L
Land Footprint	100% (Base)	10%	5% (Multi-tier)
Crude Protein	10%-12%	14%-16%	17%-20%
Disease Risk	Moderate	High	Low (Regulated)

➤ Comparative Analysis

Comparative field analysis indicates that IoT-enabled grow chambers achieve a 6- to 8-fold increase in forage production yield per square meter compared to traditional field farming [14].

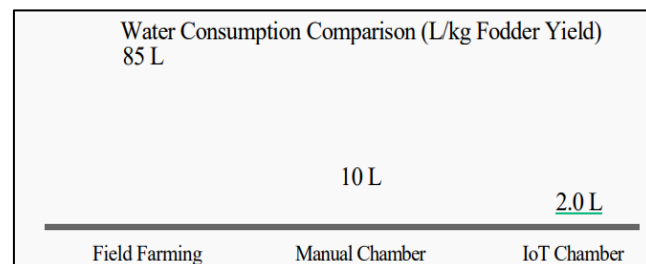


Fig 5 Comparison of Water Consumption Across Production Methods.

IV. SYSTEM IMPLEMENTATION

The complete IoT hydroponic fodder chamber prototype was constructed using a multi-tier vertical rack structure housed in an insulated enclosure.

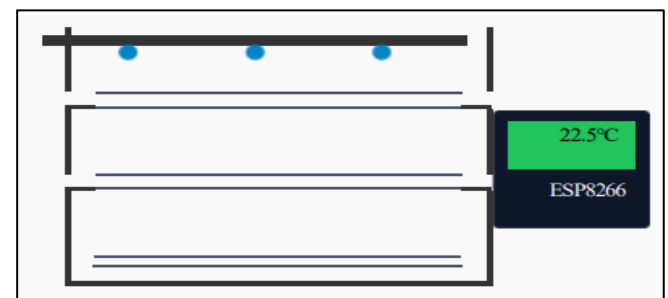


Fig 6 Mechanical Layout of Multi-Tier Hydroponic Grow Chamber.

➤ Advantages of IoT System

- **Water Conservation:** Recirculating misting systems consume 95% less water per kilogram of fodder.
- **Land Footprint Reduction:** Vertical multi-tier tray stacking increases spatial land efficiency by up to 2000%.
- **Year-Round Harvest Reliability:** Automated environmental control insulates crop production from outdoor weather volatility.
- **Enhanced Nutritional Density:** Sprouted fodder provides a highly bioavailable nutrient profile.

➤ System Limitations

Despite its significant performance benefits, real- world deployment of IoT-hydroponic chambers presents several technical challenges:

Table 3 Technical Limitations and Mitigation Strategies

Identified Limitation	Root Cause	Engineering Mitigation Strategy
Initial Capital Expense	Sensors, controllers, pumps	Use low-cost modular components (NodeMCU).
Power Dependency	Continuous Wi-Fi & pumps	Integrate 12V DC solar PV battery backup.
Fungal Pathogens	High humidity, stagnant air	Deploy VPD-driven exhaust ventilation.

➤ *Practical Applications*

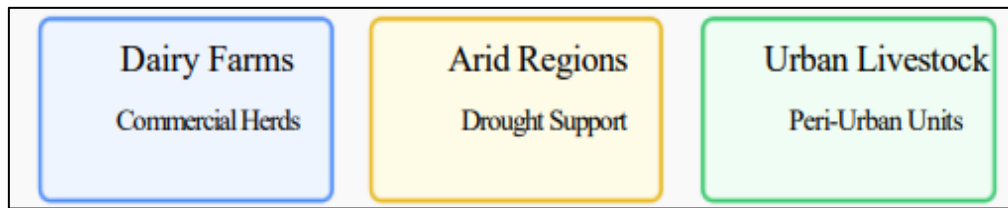


Fig 7 Key Deployment Domains for Automated Fodder Chambers.

➤ *Future Scope & Roadmap*

Future development of IoT hydroponic grow chambers focuses on integrating advanced intelligence, edge processing, and sustainable energy infrastructure [17].

Table 4 Technology Enhancement Roadmap

Research Domain	Advanced Technology Integration	Target Metric
Computer Vision (AI)	Edge-AI (ESP32-CAM) image analysis	Identify mold within 6 hours.
Predictive Analytics	Machine learning misting models	Reduce power by 25%.
Renewable Energy	Direct PV-Solar Integration	100% off-grid autonomy.

• *AI-Driven Mold Detection*

Integrating low-cost camera modules like the ESP32-CAM allows onboard Convolutional Neural Networks (CNNs) to analyze growing fodder mats in real time. Early detection of fungal hyphae enables targeted isolation of affected trays before mold spreads throughout the chamber.

➤ *Economic Feasibility Analysis*

To evaluate the financial viability of small-scale IoT hydroponic chambers, a comprehensive cost analysis was conducted for a prototype unit producing 25 kg of fresh maize fodder daily.

$$\text{Total Daily Operating Cost} = C_{\text{seed}} + C_{\text{water}} + C_{\text{electricity}}$$

Using average material costs (Maize seed @ \$0.25/kg, Electricity @ \$0.08/kWh), the production cost per kilogram of hydroponic green fodder is approximately \$0.05 to \$0.07/kg. Compared to commercial green forage prices during dry seasons (\$0.15-\$0.20/kg), automated chambers achieve full capital payback within 8 to 11 months.

V. CONCLUSION

This paper presents a comprehensive survey on IoT-enabled hydroponic fodder grow chambers. By replacing manual management with closed-loop microclimate regulation using the NodeMCU ESP8266 microcontroller, these systems achieve automated misting, precise VPD management, and continuous remote monitoring.

The system produces high-protein green fodder in a 7-day growth cycle while consuming 85-90% less water than conventional field farming. Comparative evaluations confirm substantial gains in water efficiency, spatial yield density, and forage quality.

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