

supplementary lighting measures, not only the yield benefits, but also the fruit sugar content and overall sensory quality are improved simultaneously (Qiu et al., 2023). Especially in autumn and winter, limited by natural light conditions, carbon dioxide regulation technology shows stronger application potential in off-season production, providing a feasible solution for the stable supply of high-quality strawberries.

4 Strawberry Cultivation Substrate and PrecisionNutrient Management

4.1 Substrate type selection and optimization technology

Soilless strawberry growing is key in modern farming, using water-based and media-based methods. These approaches prevent soil diseases while improving fruit quality and yields (Rathod et al., 2021; Hutchinson et al., 2025). Tests show mixing worm compost with coconut fiber (0.5:0.1 ratio) creates better water/nutrient conditions for plant growth (Tang et al., 2024). Different media serve different purposes - rockwool helps fruiting while coconut fiber supports leaf growth (An et al., 2025). Container size matters too - 830 cm³ coconut fiber pots work well for 6-month crops (Lee et al., 2023). Adding organic materials like manure boosts soil life and fruit flavor (Bai et al., 2025).

4.2 Precision fertilization and nutrient regulation technology

IoT-based watering systems now automate fertilizer and water delivery. Sensor systems cut chemical use by 38% and water by 26% (Bonelli et al., 2024; Hutchinson et al., 2025). Changing nutrient mixes during growth stages, especially adjusting N/K and K/Ca ratios, improves plant health and fruit quality (Yu et al., 2023). Combining root and leaf feeding with balanced NPK reduces waste while nourishing plants (Kumar et al., 2025).

4.3 Comprehensive optimization strategy for substrate and nutrient management

Combining good media with smart watering gives best results. Water-holding mixes (like worm compost-coconut blends) with sensor systems grow stronger plants (Bonelli et al., 2024; Tang et al., 2024; Hutchinson et al., 2025). Mixing organic (compost) and mineral fertilizers maintains both yields and soil health (Yadav et al., 2010; Barooah and Datta, 2020; Prasad et al., 2022; Bai et al., 2025). For water systems, keeping pH stable with buffers like MES helps roots take up nutrients (Yafuso and Boldt, 2024).

5 Facility Design and Year-round Control Model

5.1 Comparison of greenhouses, multi-span greenhouses, and smart cultivation systems

Modern greenhouse structures have become an important basic platform for promoting year-round strawberry cultivation due to their excellent environmental regulation performance. With the support of temperature control systems and artificial light sources, single greenhouses can still maintain stable yields in areas with drastic climate fluctuations, showing high adaptability and management flexibility. Multi-span greenhouses have more advantages in spatial organization, airflow balance and expansion capabilities. At the same time, the operating cost per unit area is relatively low, which is more suitable for large-scale deployment (Miyoshi et al., 2013; Wai et al., 2022; Thanthong et al., 2024). However, its regulation efficiency in dealing with extreme meteorological conditions is still limited by the insulation structure and the degree of automation integration, and the system resilience has certain limitations (Hernández-Martínez et al., 2023).

Intelligent cultivation systems (such as plant factories) represent the forefront of facility agriculture development. Such systems rely on IoT sensor networks and efficient automatic control platforms to achieve real-time feedback and precise regulation of light intensity, temperature and humidity, water supply and gas environment. In specific application scenarios such as urban agriculture and high-value crop cultivation, its high-density and high-efficiency advantages are particularly prominent. However, the high initial construction investment and complex operation and maintenance requirements are still the key issues that need to be weighed during the promotion and application process (Samaranayake et al., 2022; Wai et al., 2022; Mubarakah et al., 2023; De Oliveira Bernardo et al., 2024).

The automated environmental management platform is regarded as the nerve center of modern facility planting. The monitoring system composed of a distributed sensor network continuously collects multidimensional