Internet of Things-based Hydroponic: Literature Review

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Abstract. Hydroponics is a method of growing crops without using soil, with the benefits of controlling the environment and nutrients, conserving water, and reducing labor. The applied technology is used to improve results that have consistency. This research was conducted with the aim of knowing the IoT devices and platforms used in the development of IoT-based hydroponics. Data obtained from the website garuda.ristekbrin.go.id and www.sciencedirect.com from 2016 to 2021. This study is a literature review using the PRISMA method. This method is used for literature review using a systematic and structured basic framework. The results of this study indicate that the variables measured are Temperature, Potential Hydrogen (pH), Total Dissolve Solid, Water Temperature, Humidity, UV, Carbon Dioxide, Soil Moisture and Electrical Conductivity. The device used is the ESP8266, Arduino, and Raspberry PI with the MySQL, Thingspeak, Firebase, Domoticz, and Wyliodrin IoT Platforms.

1. Introduction

Farming is a human habit that has existed since time of immemorial. This farming activity has also changed along with the development of technology. Changes in farming activities due to technological developments exist in various aspects. Starting from the purpose of the farming activity itself, changes in plant types to changes in planting methods. One of them is the method of farming using hydroponics.

Hydroponics is a method of growing crops without using soil as a growing medium, but using nutritious water or materials containing nutrients [1]. Hydroponics itself comes from the Greek "Hydroponos" where hydro means water and ponos means power [2]. With the hydroponic planting method, the use of environmental control, nutrition, and water conservation can be directly carried out and periodically observed by farmers.

This hydroponic method can be done vertically in a narrow space such as a yard or terrace so it does not require a large space. The requirements for hydroponic growing media are: (1) water absorbant, (2) air circulation, and (3) cheap [2].

The advantages of cultivating plants using this hydroponic method include: (1) producing products that are superior in quality and quantity to conventional cultivation, (2) lower plant pests and diseases, and (3) easily control the nutrients provided [3].

Although there are many advantages and conveniences created by the hydroponic method, in the conditions of the covid-19 pandemic, there are still many farmers that use conventional methods of farming. This is because the hydroponic method is considered the same as the conventional farming method which must be controlled directly and manually. Therefore, we need a technology-based
hydroponic system that can advance agriculture by increasing quantity and optimizing yields and having better quality and making it easier for farmers to control and care for their plants. Based on developing technology, all aspects of life adapt by applying the latest technology that can provide convenience, including agriculture. Internet of things technology can be applied to this hydroponic system to provide convenience to farmers in carrying out their duties in the midst of the COVID-19 pandemic. The conveniences obtained from the application of the IoT in hydroponic farming activities include monitoring and controlling activities as well as plant care that can be done anywhere and anytime.

2. Methods
This research is a systematic review research using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method. PRISMA is a literature review method using a systematic and structured basic framework. The procedure of this research method consists of several stages, namely: 1) Preparing the background and research objectives, 2) Formulating research questions, 3) Searching for literature, 4) Selecting literature according to the criteria, 5) Practical screen, 6) Data extraction, and 7) Data synthesis [4].

2.1. Object of the Research
In this study, the object are research journals on IoT-based hydroponic methods based on the following reasons:
1. There are several additions to the IoT system in the hydroponic farming method that can assist farmers in monitoring and remotely controlling the plants being cultivated.
2. An IoT-based hydroponic system that is implemented using a specific microcontroller.
3. IoT-based hydroponics has a variety of protocols that can be customized as desired.

2.2. Method
2.2.1. Research question. Based on the background and object of the research that has been submitted, here is the questions of the research

RQ1. What variables are used in IoT-based Hydroponics research?
RQ2. What systems or devices are used in IoT-based hydroponics?
RQ3. what are the disadvantages of a platform implemented on an IoT-based hydroponic method?

2.2.2. Search Process. The process of searching for journal articles using the website garuda.ristekbrin.go.id and www.sciencedirect.com. the data search process in this case uses keywords related to hydroponics and the internet of things.

2.2.3. Inclusion and Exclusion Criteria. After carrying out the journal search step, the next procedure is to make a selection to meet the inclusion and exclusion criteria. This stage aims to determine appropriate data used in research based on the following criteria:
1. Data with a time span of 2016-2021.
2. The data comes from the website garuda.ristekbrin.go.id and www.sciencedirect.com.
3. Data related to hydroponics and IoT.

2.2.4. Quality Assessment. Data that has gone through the inclusion and exclusion criteria selection process will then be evaluated according to the quality assessment criteria as follows:
QA1: Does the journal list the Variables used for measurement?
QA2: Does the journal list the tools used to develop the system?
QA3: Does the journal list the Platform used for the IoT system?
2.2.5. **Data Collection.** Journal data that obtained from the garuda.ristekbrin.go.id and www.sciencedirect.com website and has met the criteria and quality assessment, will be extracted to answer research questions referring to RQ1, RQ2, and RQ3.

2.2.6. **Data Analysis.** Based on the results obtained at the data extraction stage, the next procedure is to perform data analysis which includes an explanation of the following points:

1. Variables measured in the development of an IoT-based Hydroponic system.
2. Devices used in the development of IoT-based Hydroponic systems.
3. The IoT platform used in the development of an IoT-based Hydroponic system.

3. **Result and Discussion**

3.1. **Search and Selection Process**

Based on the search process using the keywords hydroponics and internet of things on the garuda.ristekbrin.go.id website page, 16 (sixteen) and only 7 (seven) journals met the following inclusion and research induction criteria.

Table 1. Data of Internet of Things-bases Hydroponic Journal Research Result on the website garuda.ristekbrin.go.id that Match the Criteria

| No. | Title                                                                 | Author                                      | Journal Name                                      | Year |
|-----|-----------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------|------|
| 1   | Advanced Encryption Standard (Aes) 128 Bit Untuk Keamanan Data Internet Of Things (Iot) Tanaman Hidroponik | Roiya Ravida, and Heru Agus Santoso         | Jurnal Resti (Rekayasa Sistem Dan Teknologi Informasi) | 2020 |
| 2   | Optimalisasi Pertumbuhan Pada Sayuran Hidroponik                      | Akhmad Wahyu Dani                            | Jurnal Teknologi Elektro                          | 2020 |
| 3   | Rancang Bangun Aplikasi Mobile Berbasis Internet Of Muhamnabd Rizki Juanda Things Untuk Pemantauan Nutrisi Tanaman Selada | Muhammad Rizki Juanda                       | Jurnal Komputer, Informasi Teknologi, Dan Elektro | 2020 |
| 4   | Penggunaan Internet Of Things (Iot) Untuk Pemantauan Dan Pengendalian Sistem Hidroponik | Yodi Setiawan, Harlianto Tanudijaya, and Sandra Octaviani | Teslajurnal Teknik Elektro                        | 2018 |
| 5   | Pengembangan Greenhouse Fodder Jagung                                  | Mohammad Muftifajar, Muhammad                | Jurnal Mahasiswa Teub                             | 2019 |
| 6   | Sistem Nutrisi Tanaman Hidroponik Berbasis Internet Of Things Menggunakan Nodemcu Esp8266 Hadi   | Andi Heryanto, Jian Budiarto, and Sirojul  | Jurnal Bumigora Information Technology (Bite)      | 2020 |
| 7   | Perancangan Sistem Monitoring Hidroponik Nutrient Primadoly Nababan, Trias Andromeda, Film Technique (Nft) Berbasis Internet Of Things (Iot) and Yosua Alvin Adi Soetrisno Menggunakan Web Server Thingspeak | | Transient: Jurnal Ilmiah Teknik Elektro | 2020 |

From the website www.sciencedirect.com obtained 99 (ninety nine) titles of scientific writing using the keyword hydroponic internet of things. Then from the 99 (ninety nine) titles, 50 (fifty) titles are obtained which are research articles. After the review, 20 (twenty) journals of research articles were found that were accessible and the journals met the inclusion criteria and research induction as follows.

Table 2. Data of Internet of Things-bases Hydroponic Journal Research Result on the website www.sciencedirect.com that Match the Criteria

| No. | Title                                                                 | Author                                      | Journal Name                                      | Year |
|-----|-----------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------|------|
| 1   | Hydroponic and Aquaponic Farming: Comparative Study Based on Internet of things IoT technologies | Ibtissame Ezzahoui, Rachid Ait Abdelouahidb, Khoulun Taji, and Abdelaziz Marzaki | Procedia Computer Science                          | 2021 |
| 2   | Monitoring rocket (Eruca sativa) growth parameters using the Internet of Things under supplemental LEDs lighting | Jolan Jamal, Sadaoon Azizi, Alireza Abdollahpouri, Nasser Ghaderi, Behrooz | Sensing and Bio-Sensing Research                    | 2021 |
3.2. Quality Assessment Result

The journals that have been obtained were selected according to the quality assessment criteria referring to QA1, QA2, and QA3, so that the data in Table 3 and 4. is obtained below.

| Journal of Agriculture and Food Research | 2021 |
|------------------------------------------|------|
| Effect of different root lengths for retaining freshness of hydroponic lettuce | Rui Suo, Wengi Wang, Yidong Ma, Longsheng Fu, and Yongjie Cui |
| Physical and mechanical properties of hydroponic lettuce for automatic harvesting | Wenqi Wang, Yidong Ma, Longsheng Fu, Yongjie Cui, and Yaqoob Majeed |
| Fully Automated Hydroponic System for Indoor Plant Growth | Valibhav Palande, Adam Zeaheer, and Kiran George |
| Architecture design of monitoring and controlling of IoT-based aquaponics system powered by solar energy. | Shanhong Zhang, Yu Guo, Shuai Li, Zhiyin Ke, Huajian Zhao, Jinqi Yang, Yang Wang, Daoliang Li, Liang Wang, Wenhua Yang, and Zhih Zhang. |
| CARMEN: A framework for the verification and diagnosis of the specification of security requirements in cyber-physical systems | Ángel Jesús Varela-Vaca, David G. Rosado, Luis E. Sánchez, María Teresa Gómez-López, Rafael M. Gasca, and Eduardo Fernández-Medina |
| Monitoring system of environmental variables for a strawberry crop using IoT tools | Amaya Díaz Juan Carlos, Luzmila Rojas Estrada, Cardenas-Ruiz, Cesar Augusto, Ariza-Colpas Paola Patricia, Piñeres-Melo Marlon Alberto, Ramayo González Ramón Enrique, Morales-Ortega, Roberto César, Ovallos-Gazabon David Alfredo, and Collazos-Morales Carlos Andrés. |
| A Design of IoT-based Monitoring System for Intelligence Indoor Micro-Climate Horticulture Farming in Indonesia | Emil Robert Kaburuana, Rianto Jaya, and Harins |
| A 3.5-tier container-based edge computing architecture | Ching-Han Chen, and Chao-Tsu Liu |
| Enhancing aquaponics management with IoT-based Predictive Analytics for efficient information utilization | Divas Karimanzira, and Thomas Rauschenbach |
| How Green Can the Lettuce Be? A Case Study on Greening Initiatives in Supply Chains and Sustainable ERP Systems | Slaman, M & Haddara, M. |
| Urban surface uses for climate resilient and sustainable cities: A catalogue of solutions in London | Silvia Croce, and Daniele Vettorato. |
| The Digitisation of Agriculture: a Survey of Research Activities on Smart Farming | Manilo Bacco, Paolo Barsocchi, Erina Ferro, Alberto Gotta, and Massimiliano Ruggeri |
| Proposed Collective ICOM-based post-scarcity/post-capital networked communities | S. Mason Dambrot |
| 'Aha' moments in the water-energy-food nexus: A new morphological scenario method to accelerate sustainable transformation | Claire Hoolahan, Carly McLachlan, and Alice Larkin |
| Adaptation and development pathways for different types of farmers | L.C. Stringer, E.D.G. Fraser, D. Harris, C. Lyon, L. Pereira, C.F.M. Ward, and E. Simelton |
| Enhanced approaches to automated monitoring environmental quality in non-isolated thermodynamic system | Ondrej Kainz, František Jakab, Miroslav Michalko, Miroslav Hudák, and Rastislav Petija |

Table 3. Data of the Internet of Things-based Hydroponic Journal quality assessment from website garuda.ristekbrin.go.id.
Based on the data table 3 from the quality assessment results, it is known that there are 3 journals that meet the quality assessment criteria, namely journals number 2, 4, and 6. Meanwhile, two journals did not meet the quality and there were two journals that could not be accessed completely so that it was not possible to know their eligibility to be used in this study.

**Table 4.** Data of the Internet of Things-based Hydroponic Journal quality assessment from website www.sciencedirect.com

| Journal Number | QA1 | QA2 | QA3 | Result |
|----------------|-----|-----|-----|--------|
| 1              | √   | √   | X   | X      |
| 2              | √   | √   | √   | √      |
| 3              | √   | X   | √   | X      |
| 4              | √   | √   | √   | √      |
| 5              | X   | X   | X   | X      |
| 6              | √   | √   | √   | √      |
| 7              | √   | X   | X   | X      |
| 8              | √   | X   | X   | X      |
| 9              | X   | X   | X   | X      |
| 10             | √   | √   | √   | √      |
| 11             | √   | √   | √   | √      |
| 12             | X   | √   | √   | X      |
| 13             | √   | X   | √   | X      |
| 14             | X   | X   | X   | X      |
| 15             | X   | X   | X   | X      |
| 16             | X   | X   | X   | X      |
| 17             | X   | X   | X   | X      |
| 18             | X   | X   | X   | X      |
| 19             | X   | X   | X   | X      |
| 20             | √   | √   | √   | √      |

Meanwhile, based on table 4 of the quality assessment results, it is known that there are 6 journals that meet the quality assessment criteria, namely journals number 2, 6, 7, 10, 11, and 20. Meanwhile, 14 journals do not meet the quality to be used in this study.

### 3.3. Data Analysis

After conducting a quality assessment, 9 journals that met the quality were then extracted to answer research questions referring to RQ1, RQ2, and RQ3.
3.4. Measured Variables
The results of the extraction from the 9 journals containing the variable points measured in the use of the IoT in the hydroponic planting method can be presented in Table 5.

Table 5. Data of the Variable Points Measured in the Journal of Internet of Things-based Hydroponic.

| No. | Variable                           | Total |
|-----|------------------------------------|-------|
| 1.  | Temperature                        | 8     |
| 2.  | Potential Hydrogen                 | 7     |
| 3.  | Total Dissolve Solid               | 2     |
| 4.  | Water Temperature                  | 2     |
| 5.  | Humidity                           | 5     |
| 6.  | UV                                 | 3     |
| 7.  | Carbon Dioxide                     | 3     |
| 8.  | Soil Moisture                      | 3     |
| 9.  | Electrical Conductivity            | 4     |

Based on the data in Table 5, there are 8 journals that analyze the temperature variable, 7 journals that analyze the potential Hydrogen (pH) value variable, 2 journals that analyze the total dissolve solid variable, 2 journals that analyze the water temperature variable, 5 journals that analyze the humidity variable, 3 journals that analyzed the UV variable, 3 journals that analyzed the carbon dioxide variable, 3 journals that analyzed the soil moisture variable, and 4 journals that analyzed the electrical conductivity variable.

3.5. Device Used
In the journal analysis process that refers to the research question RQ2, it was found that there are three devices used, namely ESP8266, Arduino, and Raspberry PI.

3.5.1. ESP8266. ESP 8266 is an additional module for microcontroller devices such as Arduino that can be connected to wifi. ESP8266 has three wifi modes including station, access point, and Both [5]. Besides being able to connect to wifi, this device also has a USB to Serial communication chip so that programming data can use a micro usb data cable.

3.5.2. Arduino. Arduino is an open source electronic kit that has the main component, namely the AVR type microcontroller chip. Using Arduino, users can easily create programs that can be erased and reprogrammed. Users can create a system using this Arduino that can use sensors and actuators as interactions with the environment [7].

3.5.3. Raspberry PI. Raspberry PI is a single board computer that is equipped with functions like a computer in general. This Raspberry PI uses a system on an ARM chip mounted on a card-sized pcb board. The operating systems that can be installed on this device are RaspbianOS and Arch Linux [8].

3.6. IoT platform used
The data obtained through the IoT device is then forwarded through the Wifi module to an IoT platform. An IoT platform is a system consisting of hardware and software used to manage IoT devices. An IoT platform is defined as middleware and infrastructure that allows users to interact with smart objects [9]. IoT platforms are useful for storing, displaying and analyzing data originating from IoT devices.

Based on the extraction of selected journals, each journal in his research uses three different IoT platforms. The different platforms used in each journal consider the advantages and disadvantages of each existing platform according to needs.

3.6.1. MySQL. MySQL is software that provides a SQL database management system or DBMS (database management system) and can be accessed by multi-users [10]. The advantages of the MySQL
platform include being free, good database capabilities, using SQL language, being able to be accessed simultaneously, being easily accessible via the internet and guaranteed security factors. There is a drawback of this platform, namely the absence of transaction processing facilities [11].

3.6.2. Thingspeak. Thingspeak is an open source platform and provides IoT applications and application programming interfaces (APIs) as data storage taken from devices using hyper text transfer protocol (HTTP) over the internet network [5]. The advantages of this platform are that it is free, easy to create data visualizations using line charts, can be connected to hardware such as Arduino microcontrollers and raspberry pi, and is relatively easy for new users. The drawback is that there are several features that require users to upgrade their accounts to get data limits for API channels and create custom charts [12].

3.6.3. Firebase. Google has a cloud and backend service called. This platform provides Real Time Database or NoSQL. The storage method uses the JSON format. Firebase can store and synchronize data using a database to each connected client/device. The updated data will be stored in the cloud and share the latest data directly to the client [13]. This platform has several advantages, namely firebase cloud messaging which can send messages and notifications for android, IOS and the web, firebase analytics can provide information about application usage and user engagement, and realtime database provides direct database services and APIs to synchronize application data throughout client and stored on the firebase cloud. The drawbacks are that if a database is updated by a user with large enough data it can affect its performance, the JSON storage format so that data migration cannot be done easily, and there are performance problems from the server provided by firebase [14].

3.6.4. Domoticz. Domoticz is an open source automation system. This platform allows inspection, monitoring, and control of third devices and can be easily accessed using a browser on the user's desktop or mobile device. This platform system uses C++ machine language. The domoticz display uses a web browser to enter the assigned ip address and add a port at the end, usually 8080. The panels on the web display are tailored to the device [15].

3.6.5. Wyliodrin. Wyliodrin is an IoT platform that supports the connection of multiple third-party systems. The platform can be used easily for data transmission and is very practical to implement on devices that are used to view variables. Wyliodrin is a programming and device control service accessible from a browser. Users can write and run programs and save them wherever the platform is [16].

4. Conclusion
The results of the analysis and discussion show that almost all research publications related to hydroponics analyzed measure the same variables, namely Temperature and Hydrogen potential (pH), and use the module device, namely ESP 8266, Arduino, and Raspberry PI. While the IoT platforms implemented are Mysql, Thingspeak, Firebase, Domoticz, and Wyliodrin adjusted with the advantages and disadvantages of each platform.

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