ABDIMAS: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang
Vol.8(4) November 2023, 572-582
p-ISSN: 2721-138X e-ISSN: 2548-7159
http://jurnal.unmer.ac.id/index.php/jpkm

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Application of smart indoor hydroponic technology to support food security

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ARTICLE INFO:

Received: 2023-09-11
Revised: 2023-10-19
Accepted: 2023-11-04

Keywords:

Food security, Green vegetables, Internet of Things (IoT), Smart indoor hydroponic

ABSTRACT

Fish provides sufficient animal protein in the island region, particularly Nongsa in Batam City. However, the demand for minerals and vitamins from vegetables is not adequately met. The inefficient use of agricultural land is a major factor in the high vegetable prices in Batam City, reducing community interest in vegetable consumption. The activity aims to address this by introducing a smart indoor hydroponic system to meet vegetable needs. Targeting economically unproductive households, especially in Dasawisma Groups, the activity involves preparation, execution with socialization on the importance of consuming green vegetables and hydroponic tool training, and an evaluation of achievements. The applied technology is smart indoor hydroponic using Internet of Things (IoT) for nutrient control. All stages of the activity have been successful, improving the group's understanding of green vegetables. Participants can independently operate the hydroponic tool with an automatic nutrient control system and cultivate various vegetables like water spinach and bok choy.

How to cite: Mardiansyah, Y., Ilmi, N., Caniago, D. P., Masril, M. A., Faruddini, R. E., & Sumardi, H. (2023). Application of smart indoor hydroponic technology to support food security. *Abdimas: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang, 8*(4), 572-582. https://doi.org/10.26905/abdimas.v8i4.11275

1. INTRODUCTION

Batam City is the largest city located in the Riau Islands, with a land area of 715 square kilometers, while the total area reaches 1,575 square kilometers. The number of islands in Batam City is 371 islands, consisting of small islands that border neighboring countries or outermost islands (Badan Statistik Kota Batam, 2022). Batam City has a tropical climate with an average temperature of 26 to 34 degrees Celsius. The terrain in Batam City is generally flat with hilly variations, with an elevation of 160 meters above sea level. The soil in Batam is predominantly red soil, which is less fertile, and the weather is often variable, so only certain crops that can grow without following specific seasons can thrive (Siregar & Nugroho, 2021, Sutarman & Miftakhurrohmat, 2019). Batam City shares its borders with neighboring countries such as Malaysia and Singapore. One of the outermost areas in Batam City, located across from Singapore, is Nongsa.

Nongsa Beach, located in the Nongsa Subdistrict in the Sambau Village, is one of the old fishing village neighborhoods in Batam City (Badan Statistik Kota Batam, 2022). Nongsa Beach consists of 3

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Neighborhood Associations (RT) and 7 Community Associations (RW), with each RT consisting of 28-30 households. Most of the residents work as fishermen, and some are engaged in fish farming (Ilmi et al., 2021). Meanwhile, the wives of the fishermen in Nongsa Beach are collectively referred to as the "Dasawisma Group," most of whom are housewives with ample leisure time but are not economically productive. The Dasawisma Group in the Nongsa Beach area consists of 20 members. Most of these women have limited formal education, up to junior high school (SMP) only. Limited formal education and skills are the reasons for the low productivity of the fishermen's wives in Nongsa Beach.

The family's source of income relies on fishing. Animal protein needs in the Nongsa Beach area, derived from fish, are well met, but the mineral and vitamin requirements from vegetables are inversely proportional. However, many essential nutrients for the body are contained in vegetables (Islaeli et al., 2020; Sari & Budiono, 2021; Sartika, 2022). The limited understanding and awareness of the people in Nongsa Beach about the importance of diverse and balanced food consumption are the reasons for their low interest in consuming vegetables. The limited vegetable production in Batam City, especially in Nongsa Beach, also makes it difficult for residents to access green vegetables. This is a significant concern because a lack of vitamins and minerals can lead to various health problems. Based on interviews and direct observations, it was found that residents of Nongsa Beach rarely consume vegetables due to the limited availability of vegetables in the area, resulting in higher vegetable prices (Sari & Pratiwi, 2018). Residents can only purchase vegetables from mobile vendors who come once a day at higher prices or buy them from the nearest market, which is quite far away, approximately 14 kilometers.

Figure 1. Distance from Nongsa Beach to the nearest market in Google Maps

The issue of vegetable availability was previously attempted to be addressed by the Dasawisma Group by growing vegetables that do not require special treatment around their homes, such as bok choy, mustard greens, and cassava leaves. However, due to infertile soil and minimal resources, the vegetables planted could not grow well. Most of the soil in Nongsa Beach is sandy and of the ultisol type. In addition, a lack of knowledge about plant maintenance, especially green vegetables, is also a constraint. Land availability is also a challenge in vegetable cultivation due to the proximity of residential areas to the coast. The fertility of the soil in the Nongsa Beach area is also low. This is to be expected because the region is a coastal area with relatively dry soil (Muna et al., 2020). The hot and dry weather during the day also hinders the growth of green vegetables.

The solution offered to address the issue of land utilization in coastal areas is to utilize the available land for vegetable cultivation using a hydroponic system (Hidayat et al., 2023). Hydroponics is designed to be automated using sensors, making it easier for partners to provide nutrients. The aim of this community service project is to increase the frequency of consumption and self-reliance in producing green vegetables for the residents of the outermost islands, especially the Dasawisma Group in Nongsa Beach, through the application of smart indoor hydroponic technology.

2. METHODS

The Community Partnership Empowerment (PKM) activity is conducted at Nongsa Beach as a continuation of the research that has been carried out using Internet of Things (IoT) technology in a system to facilitate the control of nutrient levels in hydroponic gardens so that plants can grow healthily and well. The technology that has been tested is expected to be a solution to the issue of green vegetable availability for the community, especially in Nongsa Beach. This system operates with pH sensor-based control (Figure 2).

The pH sensor embedded in the water reservoir within the hydroponic tube controls the nutrients to be delivered to the plants. With the assistance of Nodemcu ESP32 as a processing device, it processes the received data to control the water quality within the hydroponic tube. If the pH level of the water is not within the acceptable range of around 5.5 – 6.5, the system will automatically send a signal to activate a relay component as an electrical switch, and the automatic water valve will flow, replacing the water in the hydroponic tube until the desired pH level is achieved (Novia, 2021).

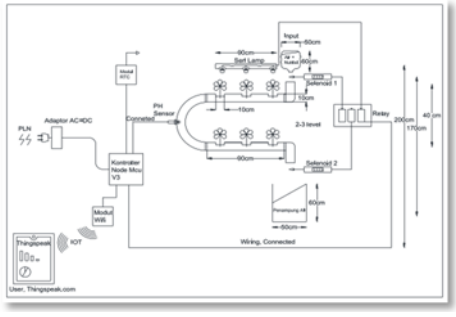

Figure 2. Hydroponic system design

The method used in this service activity is an active participation approach from activity participants through seminars and demonstrations carried out by the Community Service Team. The concept of knowledge and technology transfer carried out in this activity is divided into three stages. The first stage is the preparation of activities, the stage of implementation of coaching activities and evaluation of activities. The stages of implementation are shown in the Figure 3.

Figure 3. Stages of activity implementation

Preparation

The preparation stages were carried out to assess the initial conditions of the partner, namely the Dasawisma Group in the Nongsa Beach area, and to obtain permission from the local official, the Chairman of RW 002. After obtaining permission from the RW Chairman, discussions continued with the group's leader to understand the issues and solutions needed by the group. The first observation was conducted to assess the situation and the problems faced by the Dasawisma Group. Based on the observation results, it was found that the majority of the Nongsa Beach area consists of ultisol and sandy soil (Irawan et al., 2018). This, of course, is not conducive to the growth of green vegetables.

Table 1. Details of activity implementation

Meeting 1 (26th of June 2023)	
Activity	- Explanation of implementation methods - Introduction of the implementing group - Conduct a pretest about the importance of consuming green vegetables for health - Socialization of the importance of consuming green vegetables for health as well as myths about green vegetables
Objective	- Introducing methods of implementing service programs and introducing groups (implementation teams). - The pretest was carried out to determine the participants' initial understanding - To increase participants' knowledge and motivation about the importance of consuming green vegetables for health
Meeting 2 (10th of September 2023)	
Activity	- Introduction to the types of hydroponics - Tools and materials needed to make hydroponics - Hydroponic growing media - Nutrients needed for hydroponics
Objective	- To be able to provide knowledge to participants regarding the types of hydroponics so that they can adapt the vegetables to be planted with the appropriate type of hydroponics - To be able to determine the appropriate planting media and nutrients for the type of hydroponics you have
Meeting 3 (28th of September 2023)	
Activity	- Explanation of the process of creating a hydroponic system design - Explanation of how the sensor system works in hydroponics to regulate the timing of nutrient delivery
Objective	- To provide knowledge about the process of making hydroponics and its control system using sensors
Meeting 4 (7th of October 2023)	
Activity	- Training on the process of growing vegetables in hydroponics - Maintenance of sensor systems in hydroponics (equipped with user manual)
Objective	- Direct practice of the process of growing vegetables in hydroponics starting from sowing seeds, providing organic nutrition, and the right time for vegetables to be transferred to the hydroponic system - Maintenance needs to be carried out to maintain the service life of the hydroponic equipment
Meeting 5 (8th of October 2023)	
Activity	- Give a post test - Evaluate the benefits and drawbacks of implementing activities - Prayers - Closing
Objective	- To measure the increase in participants' understanding after carrying out the activity - Participants expressed their impressions and benefits after participating in the series of activities as well as suggestions for further activities

Implementation

Implementation of activities is carried out in several stages, including providing guidance through the presentation of materials to the Dasawisma Group on: (1) The importance of consuming green vegetables for health; (2) Types of hydroponic systems; (3) Benefits of growing with hydroponic systems; and (4) Tools and materials needed to create a hydroponic system. The guidance was delivered by bringing in a nutrition expert from the nearest community health center. The guidance sessions were conducted in two meetings. This activity can raise awareness and the community's willingness to consume green vegetables, turning it into a habit.

Training in designing and maintaining smart indoor hydroponic garden systems. Carrying out technical trials and improvements to the smart indoor hydroponic garden system design tools for each small group that has been formed. The tool has successfully run according to the criteria: (1) water can be pumped and flow according to the designed cycle; (2) The pump system will be active when the pH of the water in the hydroponic system shows <= 5.5, less than 5.5, to meet the plant's nutritional needs; (3) The Real time clock (RTC) module will activate the bulb or LED light to meet the plant's need for light for 8 hours a day; and (4) The system created is able to display the results of monitoring nutritional needs, pH and light to users via the ThinSpeak website in real time, green with a smart indoor hydroponic garden system that has been designed.

Lecturers in the field of industrial engineering provide training on plans for distribution and commercialization of harvested crops. Lecturers and students provide training on maintaining the smart indoor hydroponic garden system and plants until they reach harvest age. Details of activity implementation are presented in the Table 1.

Evaluation

As a benchmark for the success of implementing this activity, the service team will carry out an activity evaluation. Evaluation is carried out based on the service implementation stage which is divided into 3 assessment aspects, namely: (1) initial understanding of the importance of consuming green vegetables for health is measured through administering a pre-test and post-test; (2) The role and involvement of the Dasawisma Group; and (3) Increasing the understanding and skills of the Dasawisma Fishermen Group in growing green vegetables using the smart indoor hydroponic garden system.

3. RESULTS AND DISCUSSION

Results

The target of implementing this Community Partnership Empowerment (PKM) activity is the Dasawisma Group on Nongsa Beach. The implementation of this activity is carried out in several stages. In the preparation stage, the activity implementation team consisting of lecturers and service students carried out direct observations twice to find out the initial situation by visiting the location. The team discussed with the head of the Dasawisma Group, Mrs. Raja Komariah, and asked permission from local officials, namely the Head of RW 002. The members of the Dasawisma Group consisted of 20 people. Most of the group members are housewives (IRT) with an age range of 41 – 50 years (60%). Participant data are presented in the Table 2.

Table 2. Age range

Age (Years)	Amount	Percentage (%)
31 - 40	5	25
41 - 50	12	60
51 - 60	3	15%

Table 3. Participant occupation

Occupation	Amount	Percentage (%)
Merchant	4	20
Household	14	70
Others	2	10

As many as 60% of participants aged 41 – 50 years had a positive impact on this activity. This is because in this age range women are still relatively energetic and productive and because 70% are housewives so they have enough time to manage hydroponics later. Based on the results of the discussion, the problem that was often raised was the difficulty of getting green vegetables. The vegetables sold by traveling traders are quite high and the types are limited. The team implementing service activities submits activity plans by explaining the aims and objectives of implementing activities based on the results of observations and providing an explanation of the stages of implementing activities.

First, the implementation team provided outreach about the importance of consuming green vegetables for health according to the Ministry of Health, which was delivered by health workers from hospitals around the Nongsa Beach area (Figure 4). This activity aims to increase community motivation and awareness, especially the Dasawisma Group, to continue consuming green vegetables.

Figure 4. Socializing the importance of consuming green vegetables

The material presented is the benefits of vegetables for health, the risks of insufficient vegetable intake, and the frequency of vegetable consumption recommended by the Ministry of Health. In this activity, it can be seen that participants actively participate by asking questions and recording information that is considered important.

The second activity carried out was material about hydroponic systems delivered by experts in the field of food technology. The target audience for this activity is village officials who will later participate in helping with hydroponic maintenance (Figure 5).

Figure 5. Presentation of how hydroponics works and how to maintain

The material presented starts from the types of hydroponics. Hydroponic system trials are carried out to provide participants with an understanding of how the sensor system works. Sensor system trials

were carried out to determine the accuracy of the pH sensor used. If the water pH sensor shows 5.5, the pump will automatically add nutrients to the water. Based on the test results, the tool has been running successfully and meets the expected criteria (Figure 6). The training on the process of planting vegetables in hydroponics begins with the seed sowing process, and it takes approximately 12 days for the seeds to be ready for planting (Figure 7). To assist in the maintenance process, the team has prepared a guidebook regarding the use and maintenance of the sensor system.

Figure 6. Hydroponic system

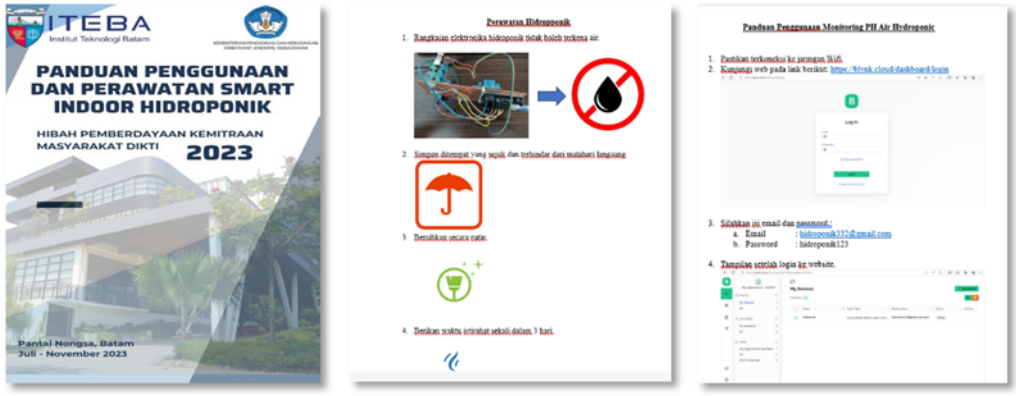

Figure 7. Training on seed sowing process and maintenance of the smart hydroponic sensor system
Figure 8. Smart indoor hydroponic manual

The final stage of this activity is evaluation. Evaluation is conducted at the end of the meeting by administering a post-test and a questionnaire to the beneficiaries of this activity, which is the Dasawisma Group in Nongsa Beach. The post-test is carried out to assess the participants' understanding of the

importance of consuming green vegetables for health. The activity is concluded with the signing of a handover report for the hydroponic system equipment from the implementing team to the local official, namely the Chairman of RW (Figure 9).

Figure 9. Signing of minutes of handover of hydroponic equipment

Discussion

To measure the success of the socialization activity on the importance of consuming green vegetables for health, a pretest and posttest were carried out on the Dasawisma Group. The following is a comparison of the results of the pretest and posttest that have been carried out (Figure 10).

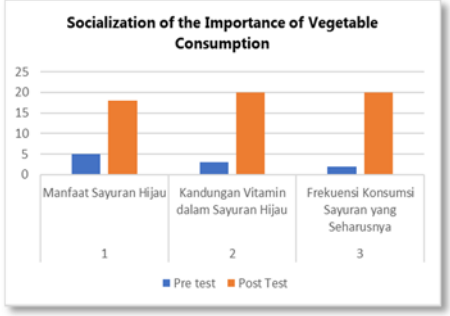

Figure 10. Result of pre-test and post-test

In Figure 10, there is an increase in the number of participants who answered correctly in the post-test compared to the pre-test. This indicates an improvement in the knowledge and understanding of the Dasawisma group about the benefits of consuming green vegetables. The most significant increase in the number of participants answering correctly was observed in the question about the recommended frequency of vegetable consumption. It can be concluded that the majority of participants have not been consuming vegetables in the recommended amounts according to the World Health Organization (WHO) guidelines. WHO generally recommends a daily consumption of 400 grams of fruits and vegetables per person, consisting of 250 grams of vegetables (equivalent to 2 ½ servings or 2 ½ cups of cooked and drained vegetables) (Menteri Kesehatan Republik Indonesia, 2014). In addition, to assess the benefits of this activity, interviews were conducted with representatives of the Dasawisma group. They expressed that having this hydroponic equipment would greatly help the community to produce vegetables independently.

Activity participant satisfaction is measured through a questionnaire filled out at the end of the activity. The following is a recapitulation of the results of the participant satisfaction questionnaire regarding the Smart Indoor Hydroponic technology provided.

Table 4. Participant Satisfaction with Smart Indoor Hydroponic Technology

Questions	Answers		Percentage (%)
	Yes	No	
The existence of a hydroponic system helps in meeting vegetable needs	20	-	100
Hydroponic systems are easy to use	17	3	85

The data in Table 4 indicates that 85% of the participants found the hydroponic system equipment easy to use, while 15% mentioned it was difficult to use. This difficulty was attributed to the age of the participants, ranging from 51 to 60 years, which led to challenges in using sensor technology.

During the implementation of this community service program, several hindering factors were encountered during the activities: (1) Scheduling difficulties: The location of the activities is a tourist destination, which often results in activities being conducted in the late afternoon; (2) Limited duration: The activity time approached sunset, and many participant questions could not be answered immediately; and (3) Limited internet access and technical skills: Participants were IRT groups with limited internet access and technical abilities. For maintenance training, local officials, specifically RT and RW members, were involved. Despite the hindering factors, the success of this activity was supported by partners and local officials, which greatly assisted in providing locations, participant coordination, and the provision of necessary facilities and infrastructure..

4. CONCLUSION AND RECOMMENDATIONS

The community service program aims to provide training on new skills and knowledge to participants, who are economically unproductive IRT (women's community groups) members, on the importance of consuming green vegetables for health. The program also includes training on hydroponic vegetable cultivation and maintenance. The targets for this program are to increase participants' knowledge and understanding of the benefits of green vegetables and their ability to maintain a hydroponic system. The implementation of this program is divided into three stages, preparation, execution, and evaluation. Supportive factors for the program's success include the local community's support in providing equipment and resources, availability of venues, and the involvement of partners. The achieved results include an improved understanding among participants about the health benefits of green vegetables and enhanced skills in maintaining hydroponic systems. It is hoped that through this program, participants can grow and produce their own vegetables, thereby contributing to food security.

There are limitations to the implementation of community service activities, including: (1) Participant difficulties in understanding the use of sensor technology in the hydroponic system can be addressed by integrating the control system into an application that can be downloaded and installed on smartphones; (2) The remote location of the community service in Nongsa Beach, which is quite far from the hydroponic system's design location (32 km away), necessitates special treatment for the designed sensor system. Therefore, the service team needs to perform sensor calibration repeatedly upon arriving at the service location; and (3) Future community service activities are expected to follow

up on the smart hydroponic program that has been initiated. This could involve conducting training on crop management and commercialization to have a greater impact on improving the community's economy.

ACKNOWLEDGEMENTS

The author would like to appreciate all parties who have been involved in this activity, especially RT and RW 002 Nongsa Beach, all administrators and members of the Dasawisma Group. The author would also like to thank the Ministry of Education, Culture, Research and Technology for funding this activity through the Community Partnership Empowerment scheme with decree no. 074/E5/PG.02.00. PM/2023 and contract agreement Number 012/LL10/AM-PKM/2023.

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