Smart Farm: Solar Chili Greenhouse by IoT Control System in Kalasin

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ABSTRACT

This research primarily aims to build the solar chili greenhouse controlled by the IoT control system (SCG-IoT) to support the farmers in Pla Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province. In so doing, this study has its objective to study the development and effectiveness of SCG-IoT. The target of this research used to evaluate the appropriateness of the innovation included 8 experts and community leaders. The tools used to collect the data included SCG-IoT, a questionnaire and a record form. The basic statistics: percentage, mean and standard deviation were used in the data analysis. The results of evaluation of innovation of SCG-IoT in overall is at the highest level. This means SCG-IoT is very appropriate in use in the research region. The temperature inside the greenhouse was 49.89 ± 5 percent, while that of outside was 35.59 ± 2 percent; and the humidity inside was 27.72 ± 4 percent. Chili could be roasted and dried within 3 days, which takes about 8-10 days less than that of the traditional drying process.

Keywords
Smart Farmer, Solar Chili Dryer, IOT Control System, Thailand

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Introduction

In the last two centuries, Thailand has faced a number of challenges that affect its economic competitiveness including, fluctuation of the world economic conditions, stricter international laws and regulations regarding competition in international trade, labors skills, and population aging, rapid technological changes requiring the country's agricultural, industrial, and service sectors to adapt to consumer demands and trading patterns, as well as the changes in development policies in southeast Asia focusing on foreign direct investment [1]. Such changes, as well as anticipated changes in future trends, will inevitably lead to more complex challenges for Thailand in order to propel its competitiveness to a more advanced stage [2].

Consequently, following the aim to be a developed country towards security, prosperity, and sustainability based upon the principles of the 'Sufficiency Economy Philosophy (SEP)' in order to further enhance the country's competitiveness, the government of Thailand has to holistically restructure its economy to create immunity, raise income levels, and reduce inequality. Therefore, Thailand has to create a new engine of growth to lead country to the development goals by focusing on 'research' and 'innovation', adopting advanced technologies to improve productivity and value-added of production and develop required labor skills [1].

At present, the global economic and social situation is faced by the emerging global crisis, Covid19, resulting in a widespread economic recession around the world. This directly affects the business sector at all levels. In this situation, to be able to survive, the farmers have to be self-reliant according to SEP, attributed to the King Bhumibol Adulyadej (King Rama IX)[1] [3], it can be seen that the government policy has adopted SEP as a solution to help farmers and people with low income to raise the income and solve the structural problems of agricultural production to enhance food nutrition and safety in order to contribute to the stability, wealth and sustainability of the people and the nation [1] [3].

Today, agriculture in Thailand still faces many problems such as low productivity and low income of farmers [4]. For farmers, inadequateness of knowledge in marketing, production planning, producing high quality agricultural products safe for consumers and environmentally friendly is the major problem [5]. The idea of 'Smart Farmers' is therefore an important mechanism used in solving such problem. In view of the National Electronics and Computer Technology Center (NECTEC)[6], which presented Smart Farm Flagship in agriculture, the main idea this is the use of electronic and computer technology including information technology in developing the supply chain and agricultural products to improve productivity, product standards and cost reduction in 4 areas: 1) reduce costs, 2) increase production quality and product standards, 3) reduce the risk of pests and natural disasters, and 4) management and knowledge transfer [6]. The approach to sustainable agricultural development is to solve the root causes of problems by raising the level of efficiency of productivity by using technology[5]. This enables farmers to apply agricultural science and technology knowledge effectively and help them access the production technology and management system.

In Thailand, Chili is a vegetable that is very important in everyday cooking. Since Thai people prefer to eat foods that are quite spicy, they grow chili for household consumption and commercial use. Chili is used to create a seasoning product such as dried chili, chili powder, chili paste, curry paste and chili salsa, etc. In Kalasin Province, Chili is one of the most important economic crops that drive the local economy. Based on the study, in this area the major obstacles to growing chili are plant diseases and pests such as root knot nematode caused by bacteria, leaf crooked disease caused by virus and anthracnose and so on.

Based on the fieldwork at Pla-Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province and based on the participatory meeting of the local stakeholders: leaders and local citizens, besides the problems mentioned above, Chili production is one of the farmers' problems. The cause of this is 'too-long-duration' (11-13 days) to dry Chili, mainly caused by the temperature conditions. To solve this issue, based the significance of greenhouse in terms of its effectiveness in agricultural productivity [7] [8] [9] [10], a huge advantage of solar energy [11] [12] [13] and Information Technology, it leads to creation of the Solar Chili Dryer or Solar Chili Greenhouse (SCG) that can automatically measure and adjust humidity and temperature to reduce the time of baking Chili. In addition, it is convenient to process during heavy harvesting and when weather conditions are not conducive to drying Chili for a specified period of time.

From the above problem, the researchers have the idea to develop SCG controlled by the IoT (Internet of Things) system [14] [15] [16] (from now on SCG-IoT) to solve the farmers' problem in the research area. In details, SCG is equipped with temperature and humidity controllers constantly assisted by IoT technology which can be operated via a mobile phone using the 'blynk' app.

II. RESEARCH OBJECTIVES

This research is carried out by means of the experimental research with its aim to solve the farmers' problem related to Chili drying in Pla-Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province. In so doing, the objectives of this study are as follows:

1) To develop SCG-IoT.
2) To study the effectiveness of SCG-IoT.

III. RESEARCH METHODOLOGY

1. Research Tools

1.1 SCG-IoT

1.2 A questionnaire probing the appropriateness of SCG-IoT

1.3 A record form of internal and external temperature and humidity of the solar greenhouse

2. Target Group

1) Community leaders and local citizens (40 people) at Pla Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province

2) Experts (5 people) for evaluating SCG-IoT, selected from Higher Education Institutions in Mahasarakham, Khon Kaen and Kalasin Provinces based on their relevant doctoral degree such as Information Technology, Mechanical Engineering, Agriculture and so on.

3. Research Methodology

1) SCG-IoT Development: this stage was carried out by the following stages.

1.1) Conduct the fieldwork at Pla Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province to study and analyze problems and needs of the community.

1.2) Study the conceptual principles applied in the preparation and creation of SCG-IoT and then develop the SCG-IoT prototype.
1.3) Design the components of SCG-IoT.
1.4) Develop and test SCG-IoT operation.
1.5) Present SCG-IoT to the experts and community representatives to consider its appropriateness and effectiveness.
1.6) Improve the operational system and create the installation and operation manuals.

2) Operational Test of SCG-IoT
2.1) Prepare SCG-IoT by testing all the involved systems.
2.2) Install SCG-IoT in the research area, Pla Khaonoi Village, Lam Klong Sub-District Community, Mueang Kalasin District, Kalasin Province.
2.3) Analyze and conclude the experimental results.

4. Statistics
In this research, the following statistics were used to study the experimental results of SCG-IoT: Percentage, Mean and Standard Deviation.

IV. RESEARCH RESULTS

1. Results of SCG-IoT Development
1.1 Based on the study on principles and concepts to design and develop SCG-IoT, the research team has studied various principles and concepts related to a framework for designing SCG-IoT as shown in Table 1.

No.	Principles and Concepts	Details
1	Solar dryer shape	The parabolic arch has many advantages; first, it is a shape that reduces wind resistance and structural costs; second, it makes the dryer get good sunlight all day long; last, it is a beautiful shape.
2	Roof material	Polycarbonate sheets have many advantages. For example, polycarbonate sheets allow sunlight to pass well but less heat radiation will pass inside the dryer. This causes a greenhouse effect which causes most of the heat to be trapped inside the dryer. In addition, polycarbonate sheet is a good heat insulator, is lightweight and easy to bend. It can be used for more than 10 years and its price per unit is similar to the glass price which is not expensive.
3	Humidity	Products dried in the dryer will eject moisture. Therefore, there must be an exhaust fan to remove the moisture from the dryer. So, there must be an air inlet to allow air to flow into the dryer instead of the sucked air.
4	Solar energy	Solar energy is one of the most alternative energy sources as it is an enormous amount of energy and does not cause any pollution toxic to environment. In addition, Thailand is an area that receives average solar energy throughout the year.
5	IoT system	The Internet of Things (IoT) is a factor influencing the world in which humans live in many areas, including high-end industries. For smart farming or smart farm

		known as Agriculture 4.0 in Thailand, IoT technology can be used to help Thai farmers, gardeners and farmers reduce waste and increase productivity.

Table 1: Principles and concepts to develop and design SCG-IoT

1.2 Design of SCG-IoT Components: the researchers adopted the framework of principles and concepts in Table 1 to design the components of SCG-IoT as shown in Figure 1.

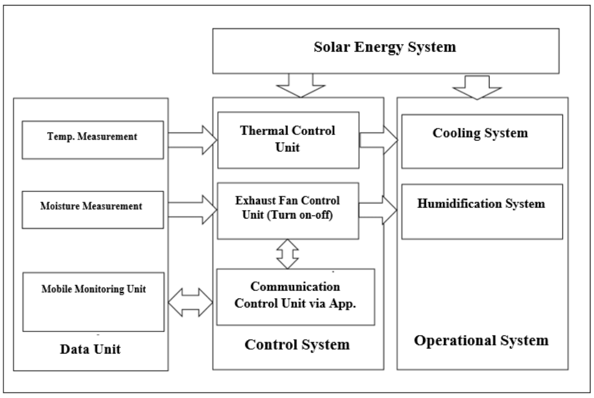

Figure 1 SCG-IoT Components

From Figure 01, SCG-IoT is consisted of 4 main components:

1) **Data Unit** refers to the unit that provides information about the moisture and temperature measurement. It acts as an input in the solar greenhouse and sent the specified conditions to the control system to decide the implementation. The mobile monitoring unit refers to an application on the mobile phone that verifies, controls or commands the equipment in the greenhouse.

2) **Control System** refers to an IoT system for controlling functions within the greenhouse, consisting of a thermal control unit, exhaust fan control unit, both of which receive information from the Data Unit and perform actions in accordance with the specified conditions. The control unit for communication via the application will receive information from the application located on the user's mobile phone and perform actions in accordance with the specified conditions.

3) **Operational System** refers to a system that operates within a greenhouse such as a cooling system and humidification system.

4) **Solar Energy System** is a system for receiving solar energy and converted it into electrical energy and send to the control system and equipment inside the greenhouse.

1.3 Structural design and architecture of SCG-IoT
From the results of the study mentioned in 1.1 and 1.2, the research team used them as a design framework of the structure and architecture of SCG-IoT shown in Figure 2 below.

Figure 2 SCG-IoT Structure and Architecture

From Figure 2, the structure and architecture of SCG-IoT consists of 1) the roof covered with a 6 mm thick, clear, colorless polycarbonate sheet; 2) polycarbonate sheet on the edge of the sheet that is placed close to the ferro-concrete floor is attached a U-shaped aluminum sheet; 3) the side steel frame is a steel box, 1x2 inches size, 2.3 mm thickness; 4) the rafter or roof frame is a steel round pipe of 1 ½ inches in diameter, thickness 2.0 mm., curved according to a design; 5), the building structure is fixed to the concrete floor with steel plate, fastened with a fluted bolt; 6) all steel work, product shelf and mounting nuts are double painted with gray rust-proof paint and the product shelf is made of aluminum.

1.4 SCG-IoT Development

From the structure and architecture of SCG-IoT, as shown in Figure 2, the research team has developed SCG-IoT, shown in figures 4 and 5.

Figure 3 **'**blynk' Mobil-Phone-Application used to control and monitor SCG-IoT

Figure 4 SCG-IoT

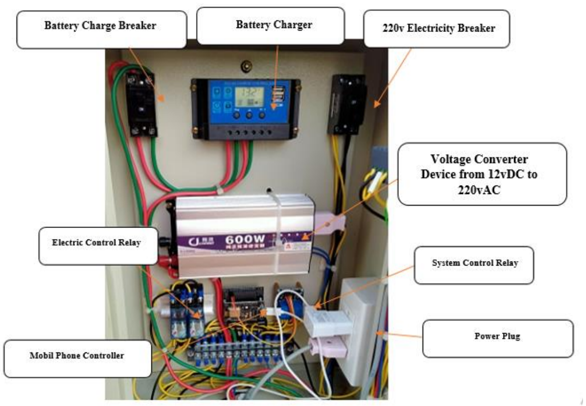

Figure 5 SCG-IoT Control System

1.5 Evaluation of SCG-IoT

The research team presented SCG-IoT to five experts and three leaders of Pla Khaonoi Village, Lam Klong Subdistrict, Muang District, Kalasin Province. The evaluation results are shown in Table 2 below.

Effectiveness List	**Appropriateness**		
	Mean	S.D.	Level
1. SCG-IoT Structure	**4.68**	**0.49**	**Very high**
1.1 insects and dust prevention	4.75	0.46	Very high
1.2 mobility	4.75	0.46	Very high
1.3 water proof	4.88	0.35	Very high
mean	**4.79**	**0.41**	**Very high**
2. Main Control Cabinet			**Very high**
2.1 Solar cell use alert-light indicator works correctly	4.88	0.35	Very high
2.2 The 220v power alert-light indicator is displayed correctly.	4.88	0.35	Very high
2.3 The humidity data acquisition unit can send data to the control unit continuously.	4.88	0.35	Very high
2.4 The battery percentage measure can send data to the control unit continuously.	4.88	0.35	Very high
2.5 Electric selector switch can work properly.	4.88	0.35	Very high
2.6 The operating mode selector switch can work properly.	4.88	0.35	Very high
2.7 The control unit has an on-off switch to turn on 1st fan, able to operate the relevant system according to the specified conditions.	5.00	0.00	Very high
2.8 The control unit has 2nd fan on-off switch and can operate the relevant system according to the specified conditions.	5.00	0.00	Very high
Mean	**4.91**	**0.2**	**Very**

		9	**high**
Total	**4.88**	**0.33**	**Very high**

Table 2: Evaluation Results of SCG-IoT

From Table 2, the result of the evaluation indicates the highest effectiveness of SCG-IoT (Mean = 4.88 and S.D. = 0.33). The appropriateness of all studied items is at the highest level.

2. Results of SCG-IoT Effectiveness Evaluation

The researchers conducted SCG-IoT developed as follows:

2.1) Temperature and humidity testing inside and outside solar greenhouse

The research team put 5 kg of fresh chili into the developed SCG-IoT and tested the humidity. The test results are shown in Table 2.

No.	Time	Internal Temp.	External Temp.	Internal Humidity
1	8:00 AM	36.0	32.0	36.0
2	9:00 AM	45.0	33.0	34.0
3	10:00 AM	48.0	34.0	31.1
4	11:00 AM	47.5	34.0	30.6
5	12:00 PM	51.7	36.5	27.5
6	1:00 PM	54.0	37.0	24.6
7	2:00 PM	54.0	37.0	24.4
8	3:00 PM	54.3	38.0	24.3
9	4:00 PM	54.3	38.0	24.3
10	5:00 PM	54.0	37.0	24.1
11	6:00 PM	50.0	35.0	24.0

Table 3: Comparative results of temperature and humidity inside and outside the greenhouse

The test results showed that the temperature inside the solar plant was always hotter than the outside temperature.

2.2) The quality of Chili in SCG-IoT (see Figure 4)

Figure 4 Quality of Dried Chili by SCG-IoT

From picture 4, baking chili reduces the moisture in the chili until it becomes dried chili in just 3 days with normal weather conditions and the chilies are red, dry thoroughly (which takes about 8-10 days less than that of traditional natural dried chili, and must be in full sun days).

VI. DISCUSSION

The development of SCG-IoT consists of 1) a 2x2 meter greenhouse and a solar drying system and 2) a structure of greenhouse, a thermal control system and an IoT system consisting of a solar greenhouse and a main control cabinet which can be operated via a mobile phone using the 'blynk' App. SCG-IoT can prevent insects and dust, easy to move as it has wheels and can be locked to prevent movement. The results of evaluation of innovation of SCG-IoT in overall is at the highest level. This means SCG-IoT is very appropriate in use at the research area. After testing, it was found that the temperature and humidity inside and outside the solar greenhouse were as follows: the temperature inside the greenhouse was 49.89 ± 5 percent, while that of outside was 35.59 ± 2 percent; and the humidity inside was 27.72 ± 4 percent. Chili could be roasted and dried within 3 days. The results were consistent with Yodwinyuwong's work 'Mini Solar Dryer Greenhouse for Community' in 2017 [17]. The results of this research showed that the physical properties of the dryers could prevent insects and dust, can be moved and convenient as it has wheels. In case of raining, it is waterproof. Compared to outdoor drying from the efficiency of the dryer, it was found that the average maximum temperature inside was 61.5 °C while the maximum ambient temperature was 45.5 °C. This is significantly different from the outside temperature. The average maximum temperature was 61.5 °C.

VI. SUGGESTION

Further research should be carried out in the ready-made greenhouse that can be used in baking a variety of agricultural products and sent to farmers in communities in order to gain the highest benefits of the research results.

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