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Agriculture

AGRITOURISM DEVELOPMENT TO THE MINISTRY OF TOURISM AND SPORTS 'QUALITY STANDARD :A CASE STUDY OF LAOR FLOWER GARDEN CO., LTD., TAK PROVINCE

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Abstract

This study focuses on the development of agritourism to meet the quality standards set by the Ministry of Tourism and Sports. Using a case study of Laor Flower Garden Company Limited in Tak Province, the study aimed to achieve the following objectives: 1) To assess the suitability of Laor Flower Garden Company Limited as an agritourism destination, and 2) To determine guidelines for developing Laor Flower Garden Company Limited in accordance with the quality standards of agritourism destinations set by the Ministry of Tourism and Sports. Data was collected from interviews with 3 executives and 36 related individuals. This data was then analyzed using simple statistics. The study revealed that Laor Flower Garden Company Limited was prepared to undergo assessment to receive the standards of the Ministry of Tourism and Sports, as the preliminary assessment score according to 4 elements and 34 indexes was 79.5 percent. The evaluation results for each element were 1) score of element 1 (10 indexes): Management Potential was 21 out of 25, 2) score of element 2 (7 indexes): Supporting Potential was 20 out of 25, 3) score of element 3 (9 indexes): Service Potential was 17.5 out of 25 and 4) score of element 4 (8 indexes) Potential Attractiveness was 21 out of 25. While Laor Flower Garden Company Limited meets certain standards, there are opportunities for further improvement based on the Ministry of Tourism and Sports criteria. Here are some suggestions: 1) Enhancing the Tourist Experience: Consider opening a restaurant to cater to tourists. Ensure accessibility by providing complete facilities for the elderly and disabled. Additionally, prioritize beautification and diversification of the gardens, creating new and engaging landscapes that evolve year-on-year. 2) Promoting Sustainable Practices: Develop a compelling narrative for the garden, fostering public awareness of the organization's vision. Continuously improve the aesthetics of the gardens while prioritizing preparedness for emergencies. Cultivate collaboration with surrounding communities to enhance their involvement. 3) Encouraging Responsible Tourism: Foster environmental awareness among tourists and personnel. Promote the conservation of agriculture, resources, and the environment. Laor Flower Garden can serve as a model for sustainable practices by eliminating waste burning, implementing composting of agricultural waste, and promoting its reuse. Additionally, preserving and showcasing the local culture and traditions through storytelling has the potential to enrich the visitor experience.

Keywords: Agritourism, Flower Garden, Agribusiness

Introduction

The outbreak of the coronavirus disease 2019 (COVID-19) since 2020 has led to significant changes in people's lifestyles worldwide, including in Thailand. This has resulted in the adoption of a "new normal" lifestyle. The COVID-19 situation has caused a considerable shift in the behavior of

Thai travelers, particularly in terms of their travel preferences. With international travel restricted and large gatherings discouraged, Thai travelers have shifted from traveling abroad to exploring domestic destinations. They have become more selective in choosing safe travel destinations with lower risks of infection, especially focusing on tourist spots with pristine natural environments. Agricultural tourism has emerged as a favorable option for tourists in this new normal situation. Apart from catering to the preferences of the new generation of travelers, agricultural tourism also plays a crucial role in generating employment and income for farmers while promoting environmental conservation and preserving local social and cultural heritage. Agricultural tourism offers tourists an opportunity to learn about farming practices, local traditions, and culture, and engage in various agricultural activities, thereby acquiring new skills and knowledge. Additionally, tourists can purchase agricultural and community products, supporting local economies and sustainable development.

Over the past decade, there has been a noticeable increase in the number of farmers transitioning their farms into flower gardens or other agricultural tourist attractions. These gardens are open to tourists, offering them the opportunity to admire the beauty of flowers and providing various recreational services such as restaurants, cafes, and even resort accommodations. However, the outbreak of the coronavirus disease 2019 (COVID-19) at the beginning of 2020 has led to a decrease in the number of tourists visiting these destinations (Community Tourism Promotion and Development Division, 2021). To instill more confidence in tourists and improve the management of agricultural tourism destinations, guidelines have been developed, particularly for flower gardens open to tourists.

The Department of Agricultural Extension has developed guidelines for managing agricultural tourism destinations in line with the criteria for evaluating the quality standards of agricultural tourist attractions set by the Ministry of Tourism and Sports (2021). These guidelines are based on an evaluation form used as a tool to assess the quality standards of agricultural tourist attractions. The evaluation form consists of 4 main components and 34 indicators. To receive certification for quality standards, all 4 main components must be evaluated. Each main component is equally important, accounting for 25 percent of the evaluation.

Laor Flower Garden Company Limited in Mae Sot District, Tak Province, has transformed from primarily production plots into an agricultural tourism destination. Previously, it was not adequately prepared to meet the standards required for assessing the quality of agricultural tourism destinations. Therefore, before undergoing a standard and quality assessment, tourist attractions should be aware of their own limitations, problems, and obstacles that may arise in farm development. This preparation is essential to ensure that agricultural tourism farms meet the required quality standards and are ready to provide tourists with the highest level of service.

Research Objectives

1) To assess the suitability of Laor Flower Garden Company Limited as an agritourism destination

2) To determine guidelines for developing Laor Flower Garden Company Limited in accordance with the quality standards of agritourism destinations set by the Ministry of Tourism and Sports

Literature Review

Evaluation Criteria for Quality in Thai Agritourism Operations

In Thailand, the Office of Tourist Attraction Development, under the Department of Tourism, Ministry of Tourism and Sports (n.d.), has developed a manual for evaluating the quality standards of agricultural tourism destinations. This manual serves as a guideline for agencies and stakeholders to

set indicators and standard levels that meet the expectations of tourists and the general public. The objective is to elevate standards in the development of sustainable tourist attractions and to establish guidelines for managing the quality of agricultural tourism destinations in accordance with these standards.

Quality standard indicators for agricultural tourist attractions consist of 4 main components, 34 indicators as follows: (Office of Tourist Attraction Development)

Element 1: Management Potential of Agricultural Tourist Attractions refers to the ability to operate, plan, control, supervise, and manage tourist attractions sustainably. It consists of 10 indicators as follows:

1) Organizational management structure and tourist attraction development plan include personnel planning, budgeting, agricultural product strategies, marketing plans, etc., Set the indicator to have a weight value of = 3.

2) Establishment of a systematic area management plan includes defining areas for agricultural use, tourism areas, conservation zones, roads, parking lots, etc. Set the indicator to have a weight value of = 3.

3) Safety management for tourists includes security preparedness and basic medical treatment in the event of an accident or illness. Set the indicator to have a weight value of = 2.

4) Waste management in tourist attractions includes garbage, sewage, wastewater, and air pollution generated from tourism activities. Set the indicator to have a weight value of = 3.

5) Acceptance and cooperation with surrounding communities include participation in community enterprises, cultural preservation, and generating employment and income in the community. Set the indicator to have a weight value of = 2.

6) Establishment of a network to support tourist attractions includes collaboration with travel companies, establishing connections with other tourist attractions, and receiving support from the government and private sectors. Set the indicator to have a weight value of = 2.

7) Conservation of natural resources and the environment includes maintaining the abundance of production resources such as soil, water, forests, and ensuring environmentally safe and healthy production practices. Set the indicator to have a weight value of = 3.

8) Maintenance of public utilities and tourism resources includes keeping bathrooms and accommodations clean, maintaining roads, electricity, water, and telephone systems, as well as improving the landscape of tourist attractions. Set the indicator to have a weight value of = 2.

9) Sales promotion for adding value and developing agricultural products includes processing agricultural products, improving labeling and packaging, and raising product standards to an international level to create purchasing incentives for customers. Set the indicator to have a weight value of = 2.

10) Advertising and public relations for tourist attractions include the distribution of brochures, billboards, public relations through websites, newspapers, radio, or television. Set the indicator to have a weight value of = 3.

Element 2: Supporting Potential of Agricultural Tourist Attractions means readiness to provide basic services for tourists that are appropriate to the environment and details of tourist attractions. It is also an element that helps create an impression on tourists. It consists of 7 indicators as follows:

1) Travel routes to access tourist attractions, convenient and safe travel (Convenience is determined by the time period during which tourist attractions can be accessed per year.) Set the indicator to have a weight value = 4.

2) Availability of basic utility systems includes roads, electricity, water, telephone, and internet. Set the indicator to have a weight value of = 4.

3) Availability of accommodation for tourist services includes the presence or absence of accommodation in tourist destinations. Types of accommodation such as homestay accommodation or camping facilities. Set the indicator to have a weight value = 4.

4) Availability of Food for tourists is categorized into three levels: no food service, meals available only if ordered in advance, and restaurants serving tourist attractions. Set the indicator to have a weight value = 4.

5) Determining the appropriate number of tourists relative to the area's size involves setting a limit on the number of tourists entering tourist attractions. Extra tourists are redirected to other tourist attractions when the specified number is exceeded. Set the indicator to have a weight value = 3.

6) Preparation of personnel to receive tourists includes having staff ready to welcome tourists at all times, with sufficient staff available during the tourist season. Set the indicator to have a weight value = 3.

7) Determining the optimal travel time involves having a designated season or opening-closing period for tourist attractions suitable for tourism throughout the year. Set the indicator to have a weight value = 3.

Element 3: Service Potential of Agricultural Tourist Attractions refers to the ability to create value for products provided within the tourist attractions. It consists of 9 indicators as follows:

1) Welcoming and creating familiarity for tourists involves providing lectures, recommendations for places and tourism activities, and informing them of the rules and conduct while visiting or staying in tourist attraction areas. Set the indicator to have a weight value of 3.

2) Availability of tour guides for tourists provides comprehensive explanations and convey knowledge about tourist attractions. These guides are proficient in speaking foreign languages. Set the indicator to have a weight value of 3.

3) Daily use shops and souvenir shops provide services for tourists to purchase goods and products either for use during their visit to the tourist attractions or to take home as souvenirs. Set the indicator to have a weight value of 3.

4) Diverse activities are available within tourist attractions, including those that enhance knowledge, offer relaxation, and provide entertainment. Set the indicator to have a weight value of 3.

5) Provision of information service for tourists is conducted through documents, brochures, boards, or signs displaying information or knowledge about agriculture and demonstration procedures. Set the indicator to have a weight value of 3.

6) Vehicle services for tourists include trailers, bicycles, or vehicles to accommodate groups of tourists or individuals. Set the indicator to have a weight value of 2.

7) Providing communication services for tourists includes mail delivery, telephone calls within and outside the country, and internet service. Set the indicator to have a weight value of 3.

8) Training services and knowledge transfer are provided, including the provision of skill training equipment for self-learning, as well as group training services. Set the indicator to have a weight value of 3.

9) Services for the elderly and people with disabilities are provided. Tourist attractions are equipped with facilities to serve the elderly and disabled, including restrooms, ramps, walkways, and educational and vocational training materials tailored to their needs. Set the indicator to have a weight value of 2.

Element 4: Potential Attractiveness of Agricultural Tourist Attractions refers to their ability to create a positive impression on tourists. This consists of 8 indicators as follows:

1) Distinctiveness in agricultural technology and specialized knowledge that serves as a model for agriculture, such as soilless crop production, modern farms, are valuable for learning and knowledge transfer to tourists. Set the indicator weight value = 3.

2) Prominence in Sufficiency Economy and local wisdom includes new agricultural theories like natural farming or organic farming, and the production of biological substances to control pests, etc. Set the indicator to have a weight value of = 3.

3) Natural conditions and the beauty of tourist attractions are emphasized. These areas are naturally picturesque or have been landscaped and adorned to enhance their beauty, blending harmoniously with nature. Set the indicator to have a weight value = 4.

4) Connection with various types of tourist attractions within a 20-kilometer radius is considered. There are whether other tourist attractions, such as natural sites, ecotourism destinations, or historical landmarks, in the vicinity or not. Set the indicator to have a weight value of = 3.

5) Receiving awards, certificates, or honors from organizations or agencies related to agriculture, tourism, environment, or local culture, such as the Kinnaree Award, the Green World Award, the A (Agrotourism) symbol, the GAP certificate, etc., is considered. Set the indicator to have a weight value of = 2.

6) The distinctiveness and variety of agricultural products available for sale to tourists, such as wine, herbal soap, processed fruits, handicraft products, etc., must be considered. Set the indicator to have a weight value of = 3.

7) The uniqueness and diversity of activities in tourist attractions, such as baking, massage and herbal compresses, horseback riding, cow milking, fruit picking, shellfish raking, fishing, elephant rides, etc., must be considered. Set the indicator to have a weight value of = 4.

8) Learning about the way of life or participating in activities with farmers, including joining activities and staying overnight with farmers, experiencing the life of a farmer, participating in activities with fishermen, living together and engaging in activities with farmers, etc., should be considered. Set the indicator to have a weight value of = 3.

9) Evaluation Methods for Thai Agritourism Quality Standards

In evaluating the quality standards of agricultural tourism attractions, it consists of 4 main components and 34 indicators to receive quality standards certification for agricultural tourism destinations. The evaluation method is as follows (Office of Tourist Attraction Development, n.d.).

1) Each key element is of equal importance, accounting for 25 percent as follows:

Key Elements	Total Scores
1. Management Potential of Agricultural Tourist Attractions	25
2. Supporting Potential of Agricultural Tourist Attractions	25
3. Service Potential of Agricultural Tourist Attractions	25
4. Potential Attractiveness of Agricultural Tourist Attractions	25
Total	100

2) Framework for quality standards indicators for agricultural tourist attractions, consisting of 34 indicators, each with specified evaluation criteria. The rating scale (Rating Scales) comprises 3 levels, with score values set as follows:

Score value 1 means exceeds Standard
Score value 0.5 means meets the standard
Score value 0 means falls below standard

3) Weight scores are calculated for each indicator, reflecting the importance of that indicator, with weights assigned values between 2 and 4 points. For example:

4) Calculating the score obtained from the assessment involves multiplying the evaluation score value from step 2) by the weight value from step 3) for each indicator to obtain the total score value of that indicator. Then, sum all the scores to determine the score of the element. For example:

Indicators of Element 1 consist of 10 indicators.	**Evaluation Score A**	**Weight Value B**	**Total Score Value C = A x B**
Indicator 1.1 Organizational management structure	0.5	3	1.5
Indicator 1.2 Establishing a systematic area management plan	0	3	0
Indicator 1.3 Safety management for tourists	1	2	2
Indicator.....	...	...	....
Indicator.....	...	...	....
Total score for Element 1 : Management of Agricultural Tourist Attractions (maximum score of 25 points)			∑ .....

etc.

5) Interpreting the total evaluation scores for all four main elements according to the quality standards for agricultural tourism attractions, passing criteria will be divided into three levels as follows:

(1) Criteria for achieving excellent quality standards require a total score of 81 or higher.

(2) Criteria for achieving very good standards require a total score ranging between 71 and 80 points.

(3) Criteria for achieving good standards require a total score ranging between 61 and 70 points.

* The entity fails to meet the quality standard criteria when its total score amounts to less than 61 points.

Related literatures

Maneerat Sookkasam (2016) conducted a study on the development potential of agritourism in Dong Khilek Sub-district, Muang District, Prachinburi Province, collecting data from two groups: Thai tourists, totaling 300 people, and stakeholders in agritourism in Dong Khilek Sub-district, totaling 18 people. The research found that the agritourism potential in Dong Khilek Sub-district, Muang District, Prachinburi Province, overall, had the highest potential in various aspects. Regarding the value of tourist attractions, it was highly recognized and well-known to the general public, followed closely by being distinctive and preserving local cultural heritage in a community-based agritourism context. The tourism resources were diverse and outstanding, the agritourism attractions were abundant, and there were linkages to main or nearby tourist attractions, in that order. In terms of services, personnel exhibited friendly attitudes and excellent hospitality, and experts/guides possessed extensive knowledge, abilities, and experience, ranking highest. This was followed by the quality of tourism information services, the availability of agricultural product/gift shops, public relations, and advertising (brochures, websites, newsletters), in that order. In terms of management, it was rated high, including the processes of agritourism development, safety and asset management, sustainable natural resource management, community involvement in agritourism, and the ability to accommodate

tourist demands, in that order. In terms of the surrounding environment, it was rated high, including cleanliness and orderly surroundings, beautiful natural scenery, and a climate suitable for year-round tourism, convenient transportation access (roads and routes), and clear and visible signage with clear meanings, in that order. Regarding tourism activities, it was rated high, including visits to fruit orchards/flower gardens/decorative plant gardens/herbal gardens, agricultural product processing and agro-industry, exhibitions/demonstrations related to agricultural products, agricultural product/ souvenir/ artisanal product purchases, overnight stays with local communities in a homestay setting to experience agricultural lifestyles, which was rated as moderate. In terms of facilities, it was rated high, including the provision of public utilities (electricity, water, telecommunications), adequate and spacious parking spaces, and homestay or resort accommodations with sufficient and standard quantities, clean and adequately stocked shops, food and beverage establishments, and clean and adequately stocked restrooms, rated as moderate.

Preeda Nakaray Chanida Rodyoo and Panjaporn Kuenui. (2020) conducted a research on evaluating the tourism potential of Nopphitam District according to community-based tourism standards. This mixed-method research gathered data through in-depth interviews, group discussions, and participatory observations involving community leaders, local administrators, tourists, and operators in the area. The findings revealed that the overall tourism potential of Nopphitam District, according to community-based tourism standards, excelled in the systematic and sustainable management of natural resources or the environment, scoring the highest at 3.09 out of 4. Following that were aspects such as the quality of tourism services, economic management, social aspects, and quality of life, as well as conservation and promotion of community cultural heritage. However, community-based tourism management scored the lowest at 1.95, particularly in terms of sustainable tourism development. The research suggests that for effective community-based tourism management, emphasis should be placed on both internal and external factors. External factors include cooperation from various sectors such as government, NGOs, private organizations, or other agencies unrelated to the community, technical cooperation, preparation of various resources for communities, financial support, etc. Internal factors include the expertise and expertise of community members promoting tourism, which are factors that the community can control and determine on their own, such as skills and expertise in guiding, the quality of life of community members in terms of health, education, and economy, participation in decision-making, etc. Therefore, the research recommends stimulating the creation of participation from community members and educational institutions, research funding sources, local government organizations, and communities to foster genuine cooperation in tourism development. It also suggests collecting data in the form of Big Data that allows all organizations access to tourism data for planning and policy-making purposes for regional development.

Methodology

Data classifications

1) Secondary data collection was conducted through a comprehensive review of various documents, including information pertaining to agricultural tourism destinations such as Laor Flower Garden Company Limited. Additionally, research and academic articles from both public and private sectors were consulted. This data acquisition process specifically focused on the quality standards for agricultural tourist attractions established by the Ministry of Tourism and Sports.

2) Primary data collection was conducted through interviews with individuals directly involved in the operations of agricultural tourism destinations, specifically Laor Flower Garden Company Limited. This data collection method employed questionnaires administered to two distinct

groups: executives responsible for the current management of Laor Flower Garden Company Limited and tourists visiting agricultural tourist attractions, including Laor Flower Garden Company Limited**.**

Population and Sample

In this research, the target population consisted of two groups (Ni):

1) N1 was executives involved in the current flower garden management of Laor Flower Garden Company Limited. The researcher collected information from every executive. In other words, the entire population, a census, in which there were 3 executives involved in the operation of the flower garden, through structured interviews using focus groups.

2) N2 comprised tourists visiting the agricultural tourism attraction: Laor Flower Garden Company Limited. The objective was to survey a sample (n2) of 36 individuals using purposive sampling. Data was collected on an individual basis using a questionnaire.

Data Analysis

To address the research objectives outlined in each item, the researchers employed the following methodological steps:

1) To address research objective 1, which focuses on assessing the current environment of Laor Flower Garden Company Limited within the context of its adherence to the established criteria for agricultural tourist attractions, a comprehensive analysis was conducted. This analysis considered the four main elements and 34 associated indicators outlined in the quality standards for agricultural tourism destinations. Data analysis employed basic statistical methods including percentage, frequency, average, and weighted average calculations.

2) To address research objective 2, which is to set guidelines for developing Laor Flower Garden Company Limited to align with the quality standards of agricultural tourism destinations set by the Ministry of Tourism and Sports, the descriptive analysis methodology was employed.

Results

The results of the quality evaluation of agricultural tourist attractions established by the Ministry of Tourism and Sports are presented. The evaluation was conducted based on the current service conditions of The Flower Garden of Suan Laor during the operational period of 2022-2023. The evaluation framework comprises four main elements and 34 associated indicators.

Indicators of Element 1 Number of Indicators: 10	**Evaluation score**	**Explanation**
1.1 Organizational management structure and tourist attraction development plan	1	Documents specifying the organization's management structure, rules, regulations, and employee manuals are available. Additionally, there was a sign displaying the organizational management structure diagram for all employees to understand and follow.
1.2 Establishing a systematic area management plan	1	There was a clear map showing land use, displayed for tourists.
1.3 Safety management for tourists	0.5	There were security officers present, along with a first aid kit containing common household medicines (not expired).[1/]
1.4 Waste management in tourist attractions	1	Systematic waste management was implemented. [2/]
1.5 Acceptance and cooperation with surrounding communities	0.5	The community embraced and benefited from tourism. [3/]

Indicators of Element 1 Number of Indicators: 10	Evaluation score	Explanation
1.6 Establishment of a network to support tourist attractions	0.5	A network was established, connecting with local-level organizations.
1.7 Conservation of natural resources and the environment	1	Tourism management promoted guidelines for the conservation of natural resources and the environment.
1.8 Maintenance of public utilities and tourism resources	1	Work was conducted in accordance with the maintenance plan.
1.9 Sales promotion for adding value and developing agricultural products	0.5	Sales promotion involved adding value and developing agricultural products at the local level. (OTOP) 4/
1.10 Services for the elderly and people with disabilities	1	Media for advertising and public relations, comprising more than two types, were utilized, and the organization had its own website.

Remark :

1/ It was observed that the first aid kit, stocked with common household medicines, was readily available for garden personnel. Additionally, it could be mobilized to serve tourists upon request. Moreover, during important festival days when there was a surge in tourist numbers, the park coordinates with village health volunteers (VHVs) to provide assistance and care.

2/ It was observed that although trash cans were discreetly placed for tourists at various locations within Laor Flower Garden to avoid disrupting photographic angles, many tourists still littered along the paths while visiting the flower garden. Consequently, personnel were assigned to patrol and periodically collect the litter. Additionally, the number of aesthetically pleasing trash cans positioned in visible areas was increased to encourage tourists to take selfies and dispose of their litter in a responsible manner.

3/ It was found that the benefits received by the community were primarily related to the availability of additional recreational resources. However, regarding community involvement and participation in tourism management, efforts were limited to recruiting community members to work and participate in various activities organized by the provincial tourism authority.

4/ It was found that Laor Flower Garden has the expectation of further developing agricultural products to the level of ThaiFex.

Table 2: The evaluation results for Element 1 : Management Potential of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 1 Number of Indicators: 10	Evaluation Score A	Weight Value B	Total Score Value C = A x B
1.1 Organizational management structure and tourist attraction development plan	1	3	3
1.2 Establishment of a systematic area management plan	1	3	3
1.3 Safety management for tourists	0.5	2	1
1.4 Waste management in tourist attractions	1	3	3
1.5 Acceptance and cooperation with surrounding communities	0.5	2	1
1.6 Establishment of a network to support tourist attractions	0.5	2	1
1.7 Conservation of natural resources and the environment	1	3	3
1.8 Maintenance of public utilities and tourism resources	1	2	2
1.9 Sales promotion for adding value and developing agricultural products	0.5	2	1
1.10 Services for the elderly and people with disabilities	1	3	3
Total score of Element 1: Management Potential of Agricultural Tourist Attractions of Laor Flower Garden (Full score of 25 points)			21

The evaluation results of Laor Flower Garden in Element 2 revealed that the evaluation of the supporting potential of agricultural tourist attractions comprises seven indicators. The evaluation results are as follows:

Table 3: The evaluation results of indicators of Element 2: Supporting Potential of Laor Flower Garden

Indicators of Element 2 Number of Indicators: 7	Evaluation Score	Explanation
2.1 Travel routes to access tourist attractions	1	Travel was easily accessible throughout all seasons.
2.2 Accommodation for tourist services	1	A basic utility system and internet access were available.
2.3 Accommodation for tourist services	1	Accommodations were available to serve tourists at tourist attractions.
2.4 Food for tourists	0.5	Food services were available for tourists. 1/
2.5 Determining the appropriate number of tourists relative to the area's size	1	The number of tourists was determined to be appropriate for the capacity of the tourist attractions, and concrete actions were taken.
2.6 Personnel to accommodate tourists	0.5	Adequate personnel were available to assist tourists, but prior contact was required. 2/
2.7 Optimal travel time	0.5	Certain seasons were deemed suitable for tourism. 3/

Remark:

1/ It was found that there was a restaurant providing services to tourists, where orders were taken according to the menu. However, there was no regular cook available. The employees with cooking skills were utilized, but the restaurant still could not provide 24-hour service to tourists staying overnight in their rooms.

2/ It was found that during festivals, holidays, or peak tourist seasons, when there was a surge in visitors, Laor Flower Garden utilized personnel from other departments of Laor Flower Garden Company Limited to assist with immediate tasks. Advance contact was only required for room reservations.

3/ It was found that the garden plans to commence operations during the winter season, from around November to April. However, if there is minimal rainfall in October, the opening will be postponed for another month. Subsequently, Laor Flower Garden will undergo renovation to create a new landscape, altering its appearance to excite tourists each year they visit.

Table 4: The evaluation results for Element 2: Supporting Potential of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 2 Number of Indicators: 7	Evaluation Score A	Weight Value B	Total Score Value C = A x B
2.1 Travel routes to access tourist attractions	1	4	4
2.2 Accommodation for tourist services	1	4	4
2.3 Accommodation for tourist services	1	4	4
2.4 Food for tourists	0.5	4	2
2.5 Determining the appropriate number of tourists relative to the area's size	1	3	3
2.6 Personnel to accommodate tourists	0.5	3	1.5
2.7 Optimal travel time	0.5	3	1.5
Total score of Element 2: Supporting Potential of Agricultural Tourist Attractions of Laor Flower Garden (Full score of 25 points)			20

The evaluation results of Laor Flower Garden in Element 3 revealed that the assessment of the service potential of agricultural tourist destinations consists of nine indicators. The evaluation results are as follows:

Table 5: The evaluation results of indicators of Element 3: Service Potential of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 3 Number of Indicators: 9	Evaluation Score	Explanation
3.1 Welcoming and creating familiarity for tourists	0.5	A description of the activities, recommended locations, and rules of conduct for tourists within tourist attractions were provided. 1/
3.2 Tour guides for tourists	0.5	Tour guides or tour leaders who exclusively spoke Thai were available to assist tourists. 2/
3.3 Daily use shops and souvenir shops	0.5	A shop selling daily necessities, souvenirs, and memorabilia was available within the tourist attraction. 3/
3.4 Diverse activities in tourist attractions	1	Tourist destinations offered two or more types of additional activities for tourists to learn, relax, or be entertained.
3.5 Information services of tourists	1	Knowledge services and information about tourist attractions were provided, along with demonstrations on how to participate.
3.6 Vehicle services for tourists	0	Vehicle services for sightseeing were not available. 4/
3.7 Communication services for tourists	1	Three or more types of communication services were available.
3.8 Training services and knowledge transfer	1	Places providing training and transferring knowledge to tourists were available.
3.9 Services for the elderly and people with disabilities	0.5	Arrangements were made for services catering to the elderly and disabled, including accessible bathrooms and ramps on at least one level floor. 5/

Remark:

1/ It was found that employees responsible for providing services described activities, recommended locations, and rules of conduct to incoming tourists. However, they lacked expertise and professional training. Nonetheless, they demonstrated a strong spirit and determination to provide excellent service. Additionally, a lecture was prepared as a video and was intended to be shown in the Laor Cafe room.

2/ It was found that Laor Flower Garden planned to recruit English-speaking tour guides or tour leaders to cater to foreign tourists.

3/ It was found that there were shops selling items within the garden. Currently, the variety of products is limited, but the garden planned to expand its offerings. Approximately 20 percent of the products were consumer goods, while 80 percent were food products. Most of these products were sourced from within Suan Lor, including other gardens, as well as from the local community and network. Additionally, some products were imported for sale.

4/ It was found that Laor Flower Garden viewing area was not extensive, but the garden features well-designed walkways, making it both beautiful and enjoyable. This encouraged visitors to stop at various points to take photographs. However, the garden planned to introduce a vehicle service to transport tourists to visit other departments of Laor Flower Garden Company Limited, in addition to touring the flower garden. This may have involved visiting the salad vegetable planting area and other relevant sections of Suan Laor Garden.

5/ It was found that shops selling items were available within the garden. Currently, the variety of products was limited, but the garden planned to expand its offerings. Approximately 20 percent of the products were consumer goods, while 80 percent were food products. Most of these products were sourced from within Laor Flower Garden, including other gardens, as well as from the local community and network. Additionally, some products were imported for sale.

Table 6: The evaluation results for Element 3: Service Potential of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 3 Number of Indicators: 9	Evaluation Score A	Weight Value B	Total Score Value C = A x B
3.1 Welcoming and creating familiarity for tourists	0.5	3	1.5
3.2 Tour guides for tourists	0.5	3	1.5
3.3 Daily use shops and souvenir shops	0.5	3	1.5
3.4 Diverse activities in tourist attractions	1	3	3
3.5 Information services of tourists	1	3	3
3.6 Vehicle services for tourists	0	2	0
3.7 Communication services for tourists	1	3	3
3.8 Training services and knowledge transfer	1	3	3
3.9 Services for the elderly and people with disabilities	0.5	2	1
Total score of Element 3: Service Potential of Agricultural Tourist Attractions of Laor Flower Garden (Full score of 25 points)			17.5

The evaluation results of Laor Flower Garden in Element 4 revealed that the assessment of the attractiveness potential of agricultural tourist attractions consists of eight indicators. The evaluation results are as follows:

Table 7: The evaluation results of indicators of Element 4: Potential Attractiveness of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 4 Number of Indicators: 8	Evaluation score	Explanation
4.1 Distinctiveness in agricultural technology and specialized knowledge	1	Two or more types of outstanding agricultural technology and specialized knowledge were available.
4.2 Prominence in Sufficiency Economy and local wisdom	1	Farming was conducted in a sufficiency economy style, utilizing at least two types of local wisdom or more.
4.3 Natural conditions and the beauty of tourist attractions	1	The area featured beautiful natural conditions, and the landscape was decorated to blend harmoniously with nature.
4.4 Connection with various types of tourist attractions	1	Two or more tourist attractions were located nearby.
4.5 Awards, certificates, or honors	0	None [1/]
4.6 Distinctiveness and variety of agricultural products	1	Five or more outstanding products were available.
4.7 Uniqueness and diversity of activities in tourist attractions	0.5	Two to four distinctive types of activities were available. [2/]
4.8 Learning about the way of life or participating in activities with farmers	1	Activities were available to learn about farmers' lifestyles, both within the tourism site and in surrounding communities.

Remark:

[1/] It was found that the garden had just commenced operations and had never received an award.

[2/] It was found that the activities organized by the garden included oil palm fruit drawing and painting, dessert-making workshops, an egg-scooping festival, and various recreational activities, especially during the New Year festival.

Table 8: The evaluation results of Element 4: Potential Attractiveness of Agricultural Tourist Attractions of Laor Flower Garden

Indicators of Element 4 Number of Indicators: 8	**Evaluation Score A**	**Weight Value B**	**Total Score Value C = A x B**
4.1 Distinctiveness in agricultural technology and specialized knowledge	1	3	3
4.2 Prominence in Sufficiency Economy and local wisdom	1	3	3
4.3 Natural conditions and the beauty of tourist attractions	1	4	4
4.4 Connection with various types of tourist attractions	1	3	3
4.5 Awards, certificates, or honors	0	2	0
4.6 Distinctiveness and variety of agricultural products	1	3	3
4.7 Uniqueness and diversity of activities in tourist attractions	0.5	4	2
4.8 Learning about the way of life or participating in activities with farmers	1	3	3
Total score of Element 4: Potential Attractiveness of Agricultural Tourist Attractions of Laor Flower Garden (Full score of 25 points)			21

Summary of the evaluation results

Interpreting the total assessment scores for all four main elements according to the quality standards for agricultural tourism attractions, passing criteria will be divided into three levels as follows:

(1) Criteria for achieving excellent quality standards require a total score of 81 or higher.

(2) Criteria for achieving very good quality standards require a total score ranging between 71 and 80 points.

(3) Criteria for achieving good quality standards require a total score ranging between 61 and 70 points.

* entity fails to meet the quality standard criteria when its total score amounts to less than 61 points.

Table 9: The summary of the evaluation results of Laor Flower Garden in accordance with quality standards for agricultural tourist attractions is as follows:

Key Element	Full Score	Evaluation Value	(Percentage)
1. Management potential of agricultural tourist attractions	25	21	84 %
2. Supporting Potential of agricultural tourist attractions	25	20	80 %
3. Service potential of agricultural tourist attractions	25	17.5	70 %
4. Potential attractiveness of agricultural tourist attractions	25	21	84 %
Total	100	79.5	79.5 %
The evaluation result indicates that the quality standards have been met at a very good level, as the total score ranges between 71 and 80 points.			

The evaluation results of Laor Flower Garden indicate that overall, the garden met the quality standards at a very good level. With a total evaluation score of 79.5 points, it was found that only Element 3, service potential of agricultural tourist attractions, met the quality standard criteria at a good level.

Study Results: Enhancing Quality Standards Through Established Guidelines

The results of the study on guidelines for enhancing the quality standards of agricultural tourist attractions can be summarized as follows:

The guidelines for enhancing the quality of agricultural tourism attractions are as follows

1) A restaurant was opened to serve tourists visiting the garden.

2) Facilities for the elderly and disabled were fully equipped.

3) Enhancements were made to the beautiful garden, creating a landscape with new features. Each year, changes were made to provide a unique experience for returning tourists, such as altering photo spots and establishing a photography studio. Additionally, cute animals like Bantam chickens were introduced.

The guidelines for developing sustainable tourist attractions are as follows

1) Sustainability initiatives within Laor Flower Garden include developing the garden's story to raise public awareness of the organization's vision. Continuous improvement of the garden involves cultivating safe vegetables for use in the garden's restaurants and for sale to tourists. Emphasis is placed on providing clean and safe food.

2) Sustainability measures related to customer/tourist services at Laor Flower Garden prioritize visitor safety. This includes providing common household medicines, hospital beds, and plans for an emergency room in the future. Additionally, Laor Flower Garden's employees are encouraged to undergo training in first aid skills to assist visitors in case of emergencies such as acute heart failure.

3) Sustainability efforts involving community engagement at Laor Flower Garden focus on providing opportunities for local enterprises, communities, and farmers to showcase quality local food. These initiatives prioritize food safety, hygiene, and environmental protection.

The guidelines for raising awareness and encouraging participation in social, resource, and environmental responsibility are as follows

1) Raising awareness among tourists and personnel about the importance of conserving agriculture, resources, and the environment was a priority. The garden aimed to serve as a model for environmental conservation by implementing practices such as refraining from burning garbage and utilizing agricultural waste to make compost for reuse.

2) Preserving culture and community traditions was essential. This included participating in merit-making events with the local village/community, such as the Kathin merit-making ceremony and the Pha Paa ceremony.

3) Providing assistance to community members, including those affected by natural disasters, was part of the garden's commitment. Initiatives include offering scholarships, donating rice, and providing various other essential products.

From the findings of the study on the opinions of Laor Flower Garden executives regarding the improvement of quality standards for agricultural tourism destinations, it was revealed that executives have proposed taking action on the following issues:

1) Developing a master plan for Laor Flower Garden, including both 3-year and 5-year plans.

2) Establishing an organizational database for analysis and decision-making in various management areas. This includes forecasting tourism demand, creating a business plan (BMC: Business Model CANVAS), and developing branding strategies.

Discussion

Based on the findings of the study on the development of agritourism in accordance with the quality standards set by the Ministry of Tourism, Travel, and Sports, a case study was conducted on Laor Flower Garden Company Limited in Tak Province. The results can be discussed in relation to related research. The evaluation of each component of the standard criteria is as follows:

(1) Element 1: Management potential of agricultural tourist attractions: Laor Flower Garden achieved an evaluation score of 84 percent, indicating excellent quality. Suan Lao Garden can further enhance the management of agricultural tourist attractions by focusing on the following areas: 1) Safety management for tourists 2) Acceptance and cooperation with surrounding communities. This aligns with the research conducted by Preeda Nakre, Chanida Rodyu, and Panjaporn Kuenui (2020), who evaluated the tourism potential of Noppitam District, Nakhon Si Thammarat Province. Their study suggested that agricultural tourism should prioritize stimulating community participation to develop sustainable agricultural tourism 3) Establishment of a network to support tourist attractions and 4) Sales promotion for adding value and developing agricultural products.

(2) Element 2 Supporting Potential of agricultural tourist attractions Laor Flower Garden: Laor Flower Garden achieved an evaluation score of 80 percent, indicating good quality. Laor Flower Garden improved the management of agricultural tourism attractions by focusing on the following areas: 1) Food for tourists. 2) Personnel to accommodate tourists. The service provided by garden personnel was a crucial factor in developing agritourism towards sustainability. This aligns with the research conducted by Preeda Nakre, Chanida Rodyu, and Panjaporn Kuenui (2020), who assessed the tourism potential of Noppitam District, Nakhon Si Thammarat Province. Their study suggested that to develop sustainable tourism agriculture, emphasis should be placed on supporting personnel with expertise and experience in conducting tours and 3) Determining the optimal travel time.

(3) Element 3 Service potential of agricultural tourist attractions: Laor Flower Garden achieved an evaluation score of 70 percent indicating good quality. Laor Flower Garden could enhance the management of its agricultural tourism attractions by implementing the following measures: 1) Welcoming and creating familiarity for tourists 2) Employing tour guides or leaders from within the community to enhance the tourism potential. This is in line with the research conducted by Maneerat Sukkasem (2016), who studied guidelines for developing the potential of agritourism in Dong Khilek Subdistrict, Mueang District, Prachinburi Province. The study highlighted the importance of service quality in enhancing tourism potential, emphasizing the need for knowledgeable and experienced tour guides to welcome and guide tourists 3) Establishing shops selling daily necessities, souvenirs, and gifts and 4) Providing services for elderly and disabled individuals.

(4) Element 4 Potential attractiveness of agricultural tourist attractions: Laor Flower Garden received an evaluation score of 84 percent, indicating excellent quality. To further enhance the management of agricultural tourist attractions, Laor Flower Garden could focus on creating distinctiveness and variety of activities within the tourist attractions.

References

Community Tourism Promotion and Development Division. (2021). *Preparation of agricultural tourism information.* Community Enterprise Promotion Division. Department of Agricultural Extension. Retrieved on April 26, 2021 from http://smce.doae.go.th/aboutus.php

Ministry of Tourism and Sports. (2021). *Manual for quality standards evaluation of agricultural tourism.* Retrieved on April 26, 2021 from https://www.car.chula.ac.th

Nakaray, P., Rodyoo, C., & Kuenui, P. (2020). Assessment of the tourism potential of nopphitam district based on cummunity-based tourism standard. *University of the Thai Chamber of Commerce Journal, Humanities and Social Sciences, 40*(2), 118-131. [in Thai]

Sookkasam, M. (2016). The guidelines of potential development of agro-tourism Tambon Dong Khilek, Muang District, Prachinburi Province. *FEU Academic Review, 10*(4), 91-112. [in Thai]

Tourism Development Office. (n.d.). *Manual for quality standards evaluation of agricultural tourism*. Department of Tourism, Ministry of Tourism and Sports.

POSTHARVEST TREATMENT TO PROLONG THE SHELF LIFE AND MAINTAIN THE QUALITY OF FRESH-CUT PRODUCE

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Abstract

Fresh-cut products have grown rapidly during the past decade, extending from the foodservice sector to the retail shelf, convenience store and fruits mobile shop. Temperature, atmosphere, relative humidity and sanitation must be regulated to maintain quality of fresh-cut. This paper will discuss an overview of physical and chemical treatments that can be applied to fruits and vegetables fresh-cut products. The purpose of this review is to present the application of both physical and chemical treatments effect on the shelf life and quality of products. Moreover, we also review about safety and limitation of the treatments. All of treatments that report in this paper effect on improve the shelf life longevity and delay the senescence of products. The results suggest that combined treatments shown better result than that in the single treatment and has commercial potential in enhancing the shelf and maintain the quality fresh-cut produce.

Keywords: Quality Control, Fresh-Cut, Postharvest Processing, Ready to Cook, Ready to Eat

Introduction

Fresh-cut fruits and vegetables have been marketed around the world over the past decade, especially in developed and developing countries. In Thailand, fresh-cut products have been popular in open air markets as well as in modern trade or supermarkets (Picture 1). Recently, fresh-cut fruits are very popular in Thailand because of the convenience to consume and easy to pay for its, especially in case of new generations (Rattanapanone et al., 2000). One of the newest products to come on line has been fresh-cut orange, mango, pineapple, longan, banana slices, jackfruit and durian.

The other terms always used to refer to fresh-cut products are minimally processed, lightly processed, and partially processed. Generally, fresh-cut produce has quite a short shelf-lift due to rapid quality deterioration and senescence. Quality of fresh-cut produce depends on the quality of the pre-harvest intact product, harvesting and its processing to be the fresh-cut products (Vilas-Boas and Kader, 2001).

Normally, fresh-cut products have higher respiration rates than the corresponding intact products. Higher respiration rates accelerated high metabolism activities result in rapid senescence. Moreover, high respiration rate can also result in more rapid loss of flavor (acid, sugars, and other components) and nutritive value. In addition, the procedures applied to maintain the quality and nutritional value of these products during storage are difficult in comparison to whole fruits and vegetables.

In this report, we will initially review the effectiveness of physical and chemical treatments on maintaining the quality and prolonging the shelf life of fresh-cut fruits and vegetables.

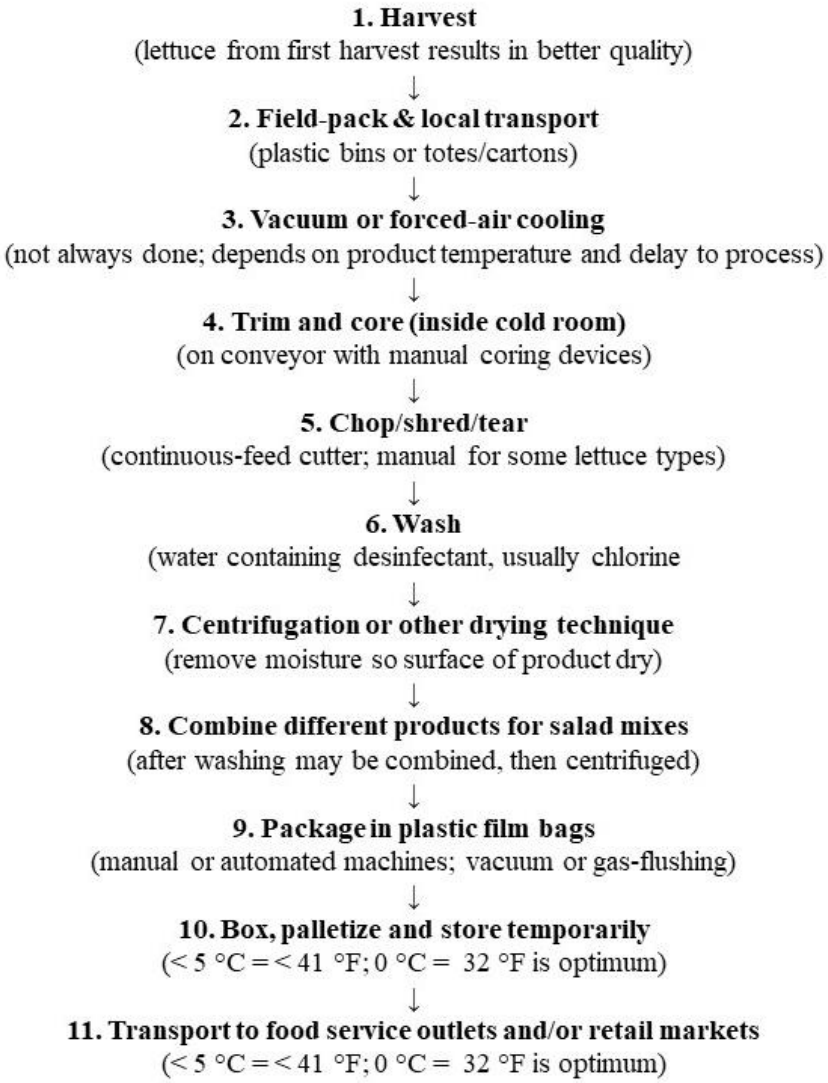
Picture 1: Display of fresh-cut produce in a modern trade in Thailand.

Processing

Fresh-cut products may be prepared at farm or source of production, depending on the perishability of raw product. An example of operations involved in fresh-cut processing is shown in Picture 2 for lettuce. The process of fresh-cut handing follows as Quality raw materials harvesting, then transport to Operation Unit as fast possible. After reception, all operations should be performed in cold, clean processing room. After trimming and separated cutting, the lettuce was clean with cold and sanitizers mixing water. Separated cutting lettuce was put in the semi-automation slicing machines. Washing the cutting lettuce immediately to removes sugars and nutrients at the cut surfaces that favor microbial growth and browning symptom. After that, washing water must be completely removed using centrifugation. Centrifuged or dried sliced lettuce were packed in suitable plastic film package. In many cases, nitrogen gas flushing is done immediately before sealing to reduce oxygen gas levels and rapidly establish modified atmosphere conditions in the package (Cantwell & Suslow, 2002).

Quality change

The physiological activities of fruits and vegetables are highly enhanced by minimal processing which involves wounding the plant tissue. The respiration and ethylene production of fresh-cut Iceberg lettuce were 2-fold higher than the whole heads Iceberg lettuce (Martinez, J., et al., 2005). Ethylene production and other physiological activities are also enhanced, resulting to decreasing of quality. Loss of quality symptoms in fresh-cut including color change (browning), off flavor, texture, and nutritional quality (sugar, acid, and vitamin content). The degree of processing and quality of the equipment (e.g., blade sharpness), significantly affect the wounding response (Adel A. Kader, 2002). Precision temperature control is required to minimize the increased respiration and metabolism of fresh-cut products. Previous studies informed that, cutting size and direction effected on the quality and shelf life of several vegetables including sweet pepper, carrot and cucumber (Abe et al., 1991, Shu et al., 1992, Abe et al., 1995)

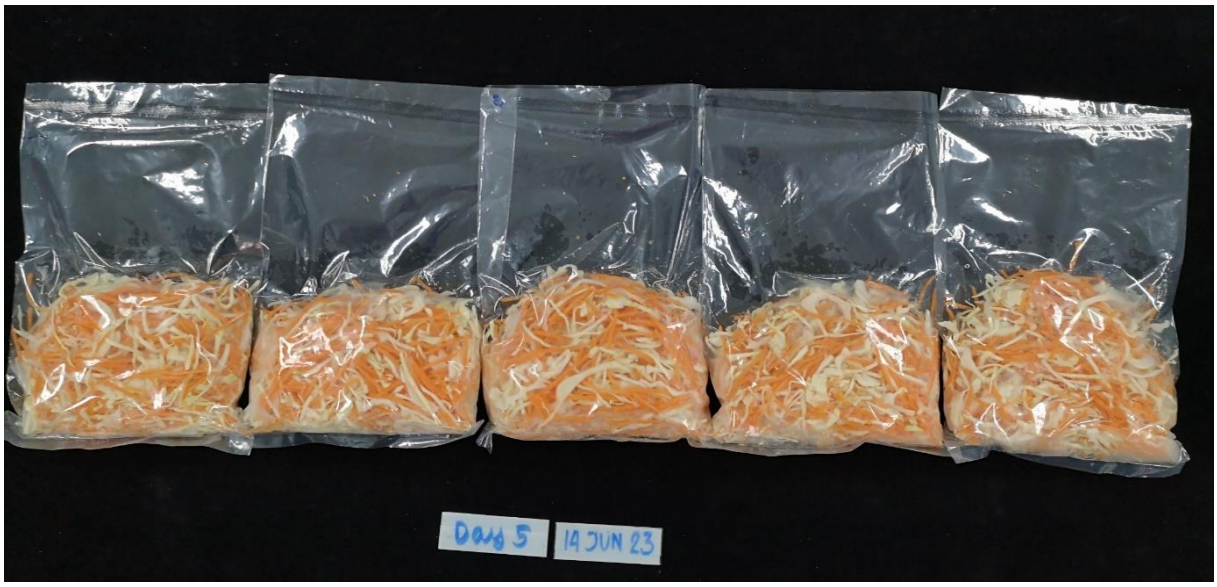


Picture 2: Flow diagram for preparation of minimally processed lettuce products at source of production. (Marita Cantwell and Trevor Suslow, 2007)

Modified Atmosphere (MA) and Packaging

Packaging is one of the most important technologies for maintaining the quality of fresh-cut by preventing the wilting, browning and off flavors. Modified atmosphere packaging (MAP) has been applied in the food industry for about 90 years to extend shelf life and maintain quality of fresh and fresh-cut foods (Day, 1996). There are many examples of the benefit of MA on fresh-cut products. For many fresh-cut products, MA and Packaging is a necessary supplement to low-temperature storage to reduce rate of deterioration. In the case of lettuce, the atmospheres effective in retarding cut edge browning are very different from the atmospheres recommended for intact lettuce heads (lettuce heads develop the disorder brown stain when exposed to CO_2 > 2%). Film package also reduce water loss from the cut surface. There have been many resent improvements and innovations in plastic films and packaging equipment specifically aimed at fresh-cut products. Packaging technology is indispensable for most fresh-cut products. The selection of the plastic film packaging material involves achieving a balance between the O_2 demand of the product (O_2 consumption by respiration)

and the permeability of the film to O_2 and CO_2. In practice, films are often selected based on the O_2 transmission rate (OTR, expressed in units of ml/m^2-day-atm). Several product factors need to be considered in selecting film packaging: the rate of respiration of the product, the specific cut, the quantity of product, and the desirable equilibrium concentration of O_2 and CO_2. Plastic film characteristics that need to be considered include the permeability of a given thickness of the plastic film to O_2, CO_2, and water at a given temperature; total surface area of the sealed package; and the free volume inside the package.



Picture 3: Fresh-cut vegetables mix consisting of carrot shreds and lettuce slices were packed in liner low density polyethylene (LLDPE).

Cooling and Low Temperature Treatments

Cold chain condition is primarily important to maintain the quality of perishable crop and their product including fresh-cut fruits and vegetables by reducing the physiological activities and physio-chemical reaction.

Cooling immediately after processing is very important for products maintaining quality. Water-cooling with ice is one of the easiest cooling methods to apply because rinsing the product after cutting is necessary to avoid browning symptom and growth of microorganism. Water-cooling after packaging is useful because there is no risk of microorganism contamination to the fresh-cut product when it is difficult to obtain cold running water. Vacuum cooling is the most effective cooling method for leafy vegetables because of its high cooling speed and reduce water loss of the product.

Low temperature controlled throughout the distribution system is necessary for fresh products. Packaging products with fully surrounding ice in a polystyrene box makes it possible to maintain a low temperature even under high temperatures during transportation.

The recommendation to store fresh-cut products as close to 0°C as possible also generally applies to items prepared from chilling-sensitive products such as sweet basil, banana, guava and pepper. Fresh-cut products are usually taken directly from cold rooms and used without transfer to warmer temperatures, conditions that favor the development of chilling injury symptoms on intact sensitive products. For fresh-cut tomatoes suitable storage temperature was 5 °C (Aguayo et al., 2004). Fresh-cut squash, cucumber, and watermelon, there are reports that storage at 2 °C to 3 °C may

result better than at 0 °C. However, for chilling-sensitive commodities in general, low temperatures retard the rate of deterioration of the fresh-cut more than they induce chilling injury. In addition, microbial safety concerns dictate that fresh-cut products always need to be kept as cold as possible (Adel A. Kader, 2002)

Picture 4: Fresh-cut vegetables mix consisting of carrot shreds and lettuce slices, onion slices and cutting fitweed (*Eryngium foetidum* L.) were packed in liner low density polyethylene (LLDPE) and hold under low temperature.

Sanitation

There are numerous sanitizers available on commercials including sodium and calcium hypochlorite, peroxyacetic acid, hydrogen peroxide, chlorine dioxide, acidified sodium chlorite and ozone. Generally, sanitizers are considered for ensuring the safety of fruits, vegetables, and their fresh-cut products.

In regulating the microorganism level of their product while shipping, several important microorganisms were considered. It was shown that aerobic mesophilic bacteria should be less than 5.0 log CFU/g and that coliform bacteria should be less than 3.47 log CFU/g; no *Escherichia coli* and no *Staphylococcus aureus* should be detected. Several disinfectant chemicals or sanitizing treatments have been used to reduce the initial microbial load on fruits destined for fresh-cut processing (USFDA, 2001). Washing in chlorinated water is the most widely applied sanitary procedure. Liquid chlorine and hypochlorite are generally used in the range of 50 to 200 ppm. Application of higher concentrations of sodium or calcium hypochlorite (2000 ppm) are reported to significantly reduce human pathogen populations on fruit surfaces (Ayhan et al., 1998; Ukuku and Sapers, 2001). On the other hand, the effect of electrolyzed acidic water for disinfection has been studied to avoid unfavorable effects of chlorine such as off flavors and/or tissue damage.

Hydrogen peroxide 150 ppm and 100 ppm chlorine (from sodium hypochloride) as sanitizing agent combined with pre-conditioning at 5°C was the suitable method of maintaining freshness and prolonging shelf life of fresh-cut onion and Pak Choy from 20-25 days and 10-14 days, respectively (Othman et al., 2005)

Cold Plasma Technologies

Cold plasma is a novel non-thermal food processing technology that uses energetic, reactive gases to inactivate contaminating microbes on meats, poultry, fruits, and vegetables. Cold plasma has been used for fresh-cut product decontamination such as apples, melons, lettuce, mangoes, and fresh fig fruit (Tappi et al., 2016; Tappi et al., 2014; Burana, 2021). The main applications of cold plasma for the food industry could be separated as food decontamination, food quality improvement, toxin degradation and surface modifications of packaging materials (Pankaj & Keener, 2017). Recently, numerous studies reported that cold plasma treatment could be a promising preservation technology for improving the quality and extending the shelf life of fresh-cut fruits and vegetables.

Food Additive

The main applications of food additives for fresh-cut produces could be grouped as antimicrobial, antioxidant, antisoftening and nutraceutical substances incorporated in foods through edible coatings for improving quality, safety, functionality and shelf-life of fresh-cut fruits and vegetables (Raybaudi-Massilia et al., 2010)

Antimicrobial agents

Antimicrobial agents used during postharvest processing are essential for controlling microbiological safety, quality, and prolonging the shelf-life of fresh-cut fruits and vegetables. Several studies have demonstrated that antimicrobials such as essential oils, organic acids, polysaccharides, and spices, incorporated into edible coatings, have been effective in controlling pathogenic and spoilage microorganisms in different fresh-cut products (Raybaudi-Massilia et al., 2010).

Antioxidant agents

Generally, fruits and vegetables, such as apples, pear, banana, mango, lettuce, and potato are especially susceptible to enzymatic browning during processing and storage. Browning not only has a negative effect on their appearance, but also may impair other sensory properties including taste, odour and texture, as well as nutritional value (Komthong et al., 2006; Jiang, 2004). Application of antioxidants as dipping treatments after peeling or cutting is the most common way to control browning of fresh-cut fruits. Numerous antioxidants were applied to reduce browning reaction in fresh-cut fruits and vegetables including ascorbic (1%), citric (1%), oxalic (0.05%) acid or their combinations incorporated into edible coatings (McHugh and Senesi, 2000).

Antisoftening agents

Softening, a major concern associated with the freshness of fresh-cut fruits, is defined as changes in the cell wall and membrane structure, which results in a decline in firmness (Wang et al., 2022). Studies have shown that the rate of fruit softening is related to calcium levels and the degradation of cell wall components (Mola et al., 2016). Many studies have been used calcium treatments to maintain firmness of fresh-cut fruits and vegetables. However, better result was found in combined with coating and suitable low temperature (Lee et al., 2003; Bico et al., 2009)

Nutraceuticals

Edible coatings may be used on the surface of many fresh-cut produce to modify the internal atmosphere (elevated in CO_2, reduced in O_2), decrease the transpiration loss, and delay the senescence during postharvest storage and handling. Recently, integration nutraceuticals into edible coatings and films to maintain and enhance nutritional value has been investigated in different contexts. Combination between high concentration of calcium (Gluconal-Cal), 5-20% Zn lactate, vitamin E (5–20% α-tocopheryl acetate) and acetylated monoglyceride with chitosan-based film for wrapping or

coating fresh-cut fruits and vegetables (Park and Zao, 2004). Edible coatings can provide an excellent vehicle to further enhance the health benefit of products where the lack of some important nutraceuticals, such as vitamin E and calcium may be compensated for by incorporating them into the coatings (Zhao, 2010)

Conclusions

In conclusion, our reviews indicated that physical and chemical treatments in this reported effect on the shelf life and quality of fresh-cut produces. These treatments help to preserve fresh, improve the surface color, maintain firmness, and reduce microbial counts. Some methods were effective to prevent browning appearance and/or delayed softening texture. However, the combination to suitable refrigeration storage (<7 °C) should be investigated to maintain fresh-cut produce quality by slowing the respiration rate, enzymatic processes, and microbial activity. In addition, more studies are also needed for a better understanding of the interactions among these physical and chemical treatments.

References

Adel A. Kader. (2002). *Postharvest technology of horticultural crops.* University of California Agriculture and Natural Resources, 535 p.

Aguayo, E., Escalona, V. & Artés, F. (2004). Quality of fresh-cut tomato as affected by type of cut, packaging, temperature and storage time. *European Food Research Technology, 219,* 492-499. https://doi.org/10.1007/s00217-004-0989-z

Ayhan, Z., Chism, G. W., & Richter, E. R. (1998). The shelf-life of minimally processed fresh cut melons. *Journal of Food Quality, 21*(1), 29-40.

Bico, S. L. S., Raposo, M. F. J., Morais, R. M. S. C., & Morais, A. M. M. B. (2009). Combined effects of chemical dip and/or carrageenan coating and/or controlled atmosphere on quality of fresh-cut banana. *Food control, 20*(5), 508-514. https://doi.org/10.1016/j.foodcont.2008.07.017

Burana, C. (2021). Effect of Plasma Treatments and Low Temperature to Some Physical and Some Physiology of Fresh Fig Fruit (*Ficus carica* L.) cv. Black Jack. *International Scientific Journal of Engineering and Technology (ISJET), 5*(1), 6–10. Retrieved from https://ph02.tci-thaijo.org/index.php/isjet/article/view/243523

Cantwell, M., & Suslow, T. (2002). *Postharvest handling systems: Fresh-cut fruits and vegetables.* In A. A. Kader (Ed.), Postharvest technology of horticultural crops (pp. 445-464). University of California, Agriculture and Nature Resources.

Day, B.P.F. , (1996) High oxygen modified atmosphere packaging for fresh prepared produce *Postharvest News and Information, 7,* pp. 31-34

Jiang Y. (2004). Advances in understanding of enzymatic browning in harvested litchi fruit. *Food Chemistry, 88,* 443-446.

Komthong, P., Katoh, T., Igura, N., & Shimoda, M. (2006). Changes in the odours of apple juice during enzymatic browning. *Food quality and preference, 17*(6), 497-504. https://doi.org/10.1016/j.foodqual.2005.06.003

Lee, J. Y., Park, H. J., Lee, C. Y., & Choi, W. Y. (2003). Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents. *LWT-Food Science and Technology, 36*(3), 323-329. https://doi.org/10.1016/S0023-6438(03)00014-8

Martinez, J., Chiesta, A., & Tovar, F. (2005). Respiration rate and ethylene production of fresh cut lettuce as affected by cutting grade. *Agricultural and Food Science, 14*(4), 354-361. https://doi.org/10.2137/145960605775897669

McHugh TH & Senesi E. (2000). Apple wraps: A novel method to improve the quality and extend the shelf life of fresh-cut apples. *Journal of Food Science, 65,* 480-485.

Mola, S., Uthairatanakij, A., Srilaong, V., Aiamla-or, S., & Jitareerat, P. (2016). Impacts of sodium chlorite combined with calcium chloride, and calcium ascorbate on microbial population, browning, and quality of fresh-cut rose apple. *Agriculture and Natural Resources, 50*(5), 331-337. https://doi.org/10.1016/j.anres.2016.12.001

Park, S. I., & Zhao, Y. (2004). Incorporation of a high concentration of mineral or vitamin into chitosan-based films. *Journal of agricultural and food chemistry, 52*(7), 1933-1939. https://doi.org/10.1021/jf034612p

Rattanapanone, N., Chongsawat, C., & Chaiteep, S. (2000). Fresh-cut fruits in Thailand. *HortScience, 35*(4), 543-546.

Raybaudi-Massilia, R. M., Mosqueda-Melgar, J., & Tapia, M. S. (2010). Edible coatings as carriers of food additives on fresh-cut fruits and vegetables. *Stewart Postharvest Review, 3*(3), 1-7.

Tappi, S., Berardinelli, A., Ragni, L., Dalla Rosa, M., Guarnieri, A., & Rocculi, P. (2014). Atmospheric gas plasma treatment of fresh-cut apples. *Innovative Food Science & Emerging Technologies, 21*, 114-122. https://doi.org/10.1016/j.ifset.2013.09.012

Tappi, S., Gozzi, G., Vannini, L., Berardinelli, A., Romani, S., Ragni, L., & Rocculi, P. (2016). Cold plasma treatment for fresh-cut melon stabilization. *Innovative Food Science & Emerging Technologies, 33*, 225-233. https://doi.org/10.1016/j.ifset.2015.12.022

Ukuku, D. O., & Sapers, G. M. (2001). Effect of sanitizer treatments on Salmonella Stanley attached to the surface of cantaloupe and cell transfer to fresh-cut tissues during cutting practices. *Journal of Food Protection, 64*(9), 1286-1291. https://doi.org/10.4315/0362-028X-64.9.1286

Vilas-Boas, E. V., & Kader, A. A. (2001). Effect of 1-MCP on fresh-cut fruits. *Perishables Handling Quarterly, 108,* 25.

Wang, Y., He, Y., Zhang, M., Li, J., Xu, X., Shi, X., & Meng, L. (2022). Slltpg3, a non-specific lipid transfer protein, acts on the cuticle synthetic pathway to delay water loss and softening of tomato fruit. *Postharvest Biology and Technology, 188*, 111899.

Zaulia, O., Razali, M., Che Omar, D., & Habsah, M. (2005). Suitable sanitizing agent and pre-conditioning temperature to prolong shelf life of minimally processed onion (*Allium cepa* L.) and green pak choy (*Brasssica rapa* cv Chinensis). *In Proceedings of APEC Symposium* (pp. 339).

Zhao, Y. (2010). *Edible coatings for enhancing quality and health benefits of berry fruits.* In Flavor and health benefits of small fruits (pp. 281-292). American Chemical Society. DOI: 10.1021/bk-2010-1035.ch018

STUDY OF THE PERFORMANCE OF HYDROPONIC SALAD CULTIVATION : A CASE STUDY OF SUAN LA-O CO., LTD., MAE SOT DISTRICT, TAK PROVINCE, THAILAND

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Abstract

The research aimed to achieve the following objectives: 1) study the hydroponic salad production process 2) analyze problems in hydroponic salad cultivation and propose solutions, and 3) to investigate the costs, net profits, and profit margins of Suan La-or Co., Ltd. This research is descriptive, utilizing data from interviews with stakeholders involved in both hydroponic salad's production and marketing of Suan La-or Co., Ltd., located in Tak Province. The study found that the production process of Suan La-or Co, Ltd. includes: 1) seedling cultivation, 2) transplanting seedlings to nursery table 1, 3) transplanting seedlings from nursery table 1 to nursery table 2, 4) transplanting seedlings into hydroponic gully, 5) harvesting, 6) trimming and packaging for distribution, and 7) cleaning sterilizing and drying the hydroponic gully for the next production cycle. The production cycle ranges from 40 to 55 days. Each process involves operations developed to efficiently cultivate hydroponic salad in the northern region of Thailand, where temperatures vary significantly between day and night during the winter season, as well as in the summer season with high temperatures. The cost of production for each type of salad is as follows: Red Oak costs 23.77 Baht per kilogram, Frillice Iceberg costs 23.14 Baht per kilogram, Green Oak costs 17.12 Baht per kilogram, and Cos costs 15.51 Baht per kilogram. Considering the selling price of 84.11 Baht, which is the average selling price of the company, it is evident that the company's net profits are as follows: Cos has the highest net profit at 32.53 Baht per kilogram, followed by Green Oak with a net profit of 29.53 Baht per kilogram, Red Oak with a net profit of 26.90 Baht per kilogram, and Frillice Iceberg with a net profit of 20.62 Baht per kilogram. The average profit margin is 32.57%."

Keywords: Hydroponics, Business Management, Agribusiness

Introduction

Growing plants without soil, also known as soilless culture, encompasses various methods, including growing plants in water containing plant nutrients, in a nutrient solution, or in soil-free potting media that contains plant nutrients. It also involves growing plants by exposing the roots directly to nutrients without soil as a planting material, among others. The term "growing plants without soil" describes the system or method of planting, which derives from two English words: "Substrate Culture" and "Hydroponics" (Direk Thongaram, 2004).

Hydroponic vegetables are often marketed as "toxin-free" due to the absence of chemical pesticides in their cultivation. However, nutrient solutions containing chemicals are used to support plant growth. These chemicals must adhere to safety limits set by the Ministry of Public Health Announcement No. 163 B.E. 2538, enforced since 2003 (Direk Thongaram, 2007). Despite this safety measure, the production volume of hydroponic vegetables remains insufficient to meet market

demand. This shortage is attributed to an increasing consumer preference for non-toxic salad vegetables, driven by a growing interest in health in line with global trends (Bodin Rasameet, 2023). Consequently, commercial hydroponic vegetable cultivation has become an appealing venture, offering premium-grade products at high prices. Popular varieties of hydroponic salad vegetables include Red Oak, Green Oak, Red Coral, Green Coral, Batavia, Butterhead, Cos, Frillice Iceberg, and Rocket (Nipaporn Saengcharatwong, 2005). Among these, Red Oak, Green Oak, Red Coral, Butterhead, and cos are the most commonly purchased for consumption.

In Tak Province, Suan La-or Company Limited has been cultivating salad vegetables using the hydroponic method. They grow four types of hydroponic salad vegetables: red oak, green oak, cos, and frillice Iceberg. The company utilizes a total of 48 tables, with each table accommodating 240 plants. However, cultivating vegetables in the northern region, characterized by significant temperature fluctuations between day and night during winter, as well as high summer temperatures, poses challenges that can impact the quality and cost of vegetable production. Specific techniques and knowledge are required to address these challenges effectively. Recognizing this, the researcher sees the importance of conducting a study to gain insights into the management of hydroponic salad vegetable production at Suan La-or Company Limited in Tak Province. This research aims to acquire knowledge that can be used to enhance the efficiency and quality of commercial vegetable production. The findings will be valuable to those interested in applying such knowledge and can serve as a model for commercial vegetable production.

Research Objectives

1) To examine the production process of hydroponic salad vegetables
2) To analyze challenges in hydroponic salad vegetable cultivation and propose solutions
3) To investigate the costs, net profits, and profit margins of Suan La-or Company Limited.

Literature Review

General Information about hydroponic salad

Hydroponic salad production is a system that allows for continuous cultivation throughout the year, utilizing minimal growing space. It efficiently manages water usage and nutrient provision essential for salad growth. This system enables the control of various environmental factors relevant to salad growth. In Thailand, salad can be categorized based on distinctive characteristics as follows: 1) Cos or Romaine lettuce, with large, thick leaves and a substantial stem, such as Cos. 2) Crisphead lettuce, with tightly wrapped leaves, crisp texture, and frilled edges, for example, Frillice Iceberg. 3) Leaf lettuce, characterized by loose heads and wavy or curled leaves, like Green Oak and Red Oak. 4) Butterhead lettuce, featuring loosely clustered heads with green outer leaves and white or yellow inner leaves, such as Butterhead (Kim et al., 2016).

Salad serves as a source of various vitamins, minerals, and phytochemicals essential for health. Generally, individuals should consume no less than 400 grams of vegetables and fruits per day. However, 65.5% of the Thai population (53 million people) consume less than the recommended standard (Phulkerd et al., 2020). Therefore, low-cost, high-quality salad cultivation presents a great opportunity for business ventures to meet consumer demand.

Costs and Returns

Costs and returns analysis employs farm accounting analysis to study costs and returns per farm, per 1 rai, or per 1 production unit. In the case of hydroponic salad production at Suan La-or

Company Limited, the cost analysis will categorize costs into fixed costs and variable costs. The components of costs and returns (Nongnuch Angyureekul, 2004) are as follows:

Costs are various expenses used for investment and production operations, classified into:

(1) Fixed costs consist of investments in various assets, including planting tables, water filtration systems, water pumps, hoses, PVC pipes, pickup trucks, accessories, carts, motorcycles, hoes, spades, knives, scissors, buckets, scales, etc. These investment costs are considered in calculating the average annual cost of production. Depreciation of these assets is accounted for as a fixed cost, which is non-cash, and is calculated on a straight-line basis using the following formula:

$$\text{Deprecation} = \frac{\text{Value of the purchased property - salvage value}}{\text{Service life}}$$

(2) Variable costs are operating expenses in production, including breeding costs, fertilizer costs, electricity costs, fuel costs, labor costs, repair costs, miscellaneous expenses, etc.

Income is the revenue generated from sales. When costs are deducted from revenue, the remaining amount is the net income. This study will analyze the profitability by assessing various cost burdens as follows:

(1) Income is calculated from the selling price multiplied by the quantity sold.

(2) Net income over total variable costs is calculated as income minus total variable costs.

(3) Net profit is calculated from revenue minus all costs, namely variable costs and fixed costs.

The profit ratio is a financial ratio used to analyze the operating results of a business. It measures the ability of the business to generate profits through efficient management (Nongnuch Angyurikul, 2004). The formula for calculating the profit ratio is as follows:

$$\text{Profit Ratio} = \frac{\text{Net profit } *100}{\text{Net sales}}$$

Thitiphan Khampu (1999) conducted a study on the production costs of celery and four types of salad vegetables under controlled environments, using hydroponic methods and plant nutrient solutions. The study analyzed the production costs of four types of celery and salad vegetables, namely Red Oak, Butterhead, and Asconia. It was found that the production costs were 8.70, 14.93, 8.53, and 11.06 baht per kilogram, respectively. Despite Butterhead having the lowest production cost, it yielded the highest return.

Natthika Suthiprasit (2016) conducted a study on the operating costs of growing hydroponic vegetables and explored the feasibility of investment. The study involved 10 hydroponic vegetable growing business operators. The results indicated that the average payback period for hydroponic vegetable growing businesses is 3 years and 10 months. The initial investment structure amounted to 3,291,000 baht, with a cost of sales in the first year reaching 2,836,800 baht. In the first year, sales amounted to 4,720,000 baht, resulting in a cash inflow of 1,442,613.29 baht. The discounted rate of return that would equate the net present value to 0 was found to be 40.50%, with a net present value of 10,876,269.31 baht. The financial analysis results from this research demonstrate the potential for investing in hydroponic vegetable growing businesses. The investment shows promise with a high return and a satisfactory payback period. In sensitivity analysis, where costs increase by 5 percent while rental income remains constant, the net cash flow received from the project was found to be greater than the initial investment, with a positive value of 9,772,814.73 baht, indicating project acceptance. Similarly, in the case where income decreases by 5 percent while costs remain constant,

the net cash flow received from the project was greater than the initial investment, with a positive value of 8,584,076.28 baht, leading to project acceptance.

Methodology

Population and Sample

The target population for this research was Suan La-or Co., Ltd. in Tak Province. The research focused on a specific case study of their commercially produced hydroponic salad vegetables. The study included four types of vegetables: Red Oak, Green Oak, Green Coral, and Philly Iceberg.

Data Collection

The types of data used and collected include:

Secondary data 1 was collected from various documents, including records related to the commercial hydroponic salad business of Suan La-or Co., Ltd., as well as research and academic articles from government and private agencies. The important secondary data for analysis pertained to four types of commercially produced hydroponic salad vegetables: Red Oak, Green Oak, Green Coral, and Fillet Iceberg.

Primary data 2 was collected through unstructured interviews with individuals involved in the production of hydroponic salad vegetables at Suan La-or Co., Ltd. The interviews included business owners and officials from the production and marketing departments. No questionnaires were used during the interview process.

Data Analysis

For data analysis, descriptive analysis was employed. Tables were compiled, and simple statistics were used to explain the results.

Results

Hydroponic salad production process of Suan Laor Co., Ltd.

The hydroponic salad pushing production process of Suan La-or Company Limited was as shown in Figure 1 and has the following details.

1) In the seedling cultivation stage, sponge sheets served as the planting material. Each sponge sheet accommodated 96 seeds. Utilizing 4 sponges, which equaled 1 sponge sheet, allows for the planting of 384 seeds. With one worker working for 8 hours, 48 sponge sheets (equivalent to 12 seed plates) could be produced, and it took 3 days for them to grow.

However, the rate of seed usage per the actual number of planted salad was calculated as follows: Planting vegetable seeds in 1 sponge pad required 96 seeds. Therefore, planting 48 sponge pads consumed 4,608 seeds. This calculation was based on the number of 12 planting tables, each capable of accommodating 240 plants, totaling 2,880 plants. Hence, the number of plants planted per seed was calculated as 2,880 divided by 4,608, resulting in 62.50 percent. This rate took into account: 1) The germination rate and 2) The culling rate before transplanting to Nursery Table 2, allowing for the selection of the strongest plants. Only the strongest plants from Nursery Table 2 were selected for transplantation to the planting table, ensuring their survival and promoting the development of strong leaves and roots.

The sponge sheets used as planting material were first moistened with water. Then, the prepared vegetable seeds were placed into the pre-drilled holes of the sponge, with 1 seed per hole. The sponge designated for seed planting was prepared with specific locations and holes for sowing seeds. When dropping seeds, they had to be inserted vertically into the sponge, ensuring that the pointy end of the vegetable seeds was facing downward. It's important to note that once vegetable

seeds are removed from the packet, they had to be used entirely. Returning them to the envelope was able to reduce the germination percentage. After all the seeds have been planted in the holes, the sponge was placed in a foam crate. An empty sponge, moistened with water, was then placed on top, and the foam crate was closed for 3 days to allow the seeds to germinate before transferring them to Nursery Table 1.

2) Transplanting seedlings to nursery table 1, each Nursery Table 1 could accommodate 24 sponge pads. It required 1 worker to move 48 sponge pads (equivalent to 2 Kindergarten 1 tables), which took approximately half an hour. The seedlings remained at Nursery Table 1 for 7 days.

3) Transplanting seedlings from nursery table 1 to nursery table 2 involved transferring all 48 sponge pads of seedlings. This task required 3 people working for 8 hours. Due to the size of the vegetables and the need to allow space for their proper growth, 12 Nursery Table 2 were required. During the transfer process, the sponge pads containing the seedlings were separated from each other. Subsequently, one sponge with one seedling was placed in each planting cup, and the planting cup was then placed into the trough. For the first fertilization, A B fertilizer was applied, with an EC value of 800-1000 and a pH of 5.5 - 6.5. Additionally, 300 ml of Trichoderma was added. The salad plants spend 7-10 days at Nursery Table 2.

4) Transplanting seedlings into hydroponic gully required 3 workers to complete the task for all 12 tables, which takes 8 hours. Each planting table was able to accommodate 240 seedlings. It's essential to complete this process before the sun became too hot to prevent the vegetables from withering or the leaves from falling off. In case of intense sunlight, the shade was required to be closed to 70% to maintain a cool temperature for both the trough and the water before planting the seedlings.

Usually, at the planting rail table, it took approximately 24-26 days for vegetables to grow. However, in the summer, this duration extended to around 35 days, while in the winter, it shortened to approximately 21 days. The planting period for all 4 types of vegetables varies by approximately 3 days. In order from fastest to slowest growth, the durations were as follows: Cos: approximately 20-22 days, Green Oak: approximately 22-24 days, Frillice Iceberg: approximately 24-26 days and Red Oak: approximately 26-28 days.

Plant protection activities during planting at the planting table should be managed as follows:

(1) Spray fermented banana juice every morning and evening at a usage rate of 250 ml of fermented banana juice per 10 liters of water. This served as a source of carbon for vegetables, especially on cloudy days when there was no sunlight for photosynthesis.

(2) Spray egg hormone every 3 - 7 days at a usage rate of 3 tablespoons of egg hormone per 10 liters of water. This served as a nutritional supplement for vegetables.

(3) Spray Larmina (Bacillus subtilis) every 3 days at a usage rate of 2 teaspoons (approximately 40 grams) per 10 liters of water. This helped prevent leaf spot disease, especially during the rainy season or alternating rainy and dry periods.

(4) Spray Set Point (Bacillus thuringiensis) with a usage rate of approximately 50 grams per 10 liters of water every 3 days to prevent various types of worms occurring in vegetables.

(5) Spray Actara (thiamethoxam) at a usage rate of 1 gram per 10 liters of water to control various aphids. When an outbreak was detected, spray for 3 consecutive days if aphids are present in large quantities.

(6) Spray fermented tea waste with liquor. Mix tea grounds soaked in white liquor at a ratio of 3 tablespoons per 20 liters of water to prevent and eliminate pests that feed on and damage the plants. This method was used when an initial outbreak was discovered.

(7) Spray wood vinegar at a ratio of 200 ml per 20 liters of water every 7 days to prevent and eliminate pests.

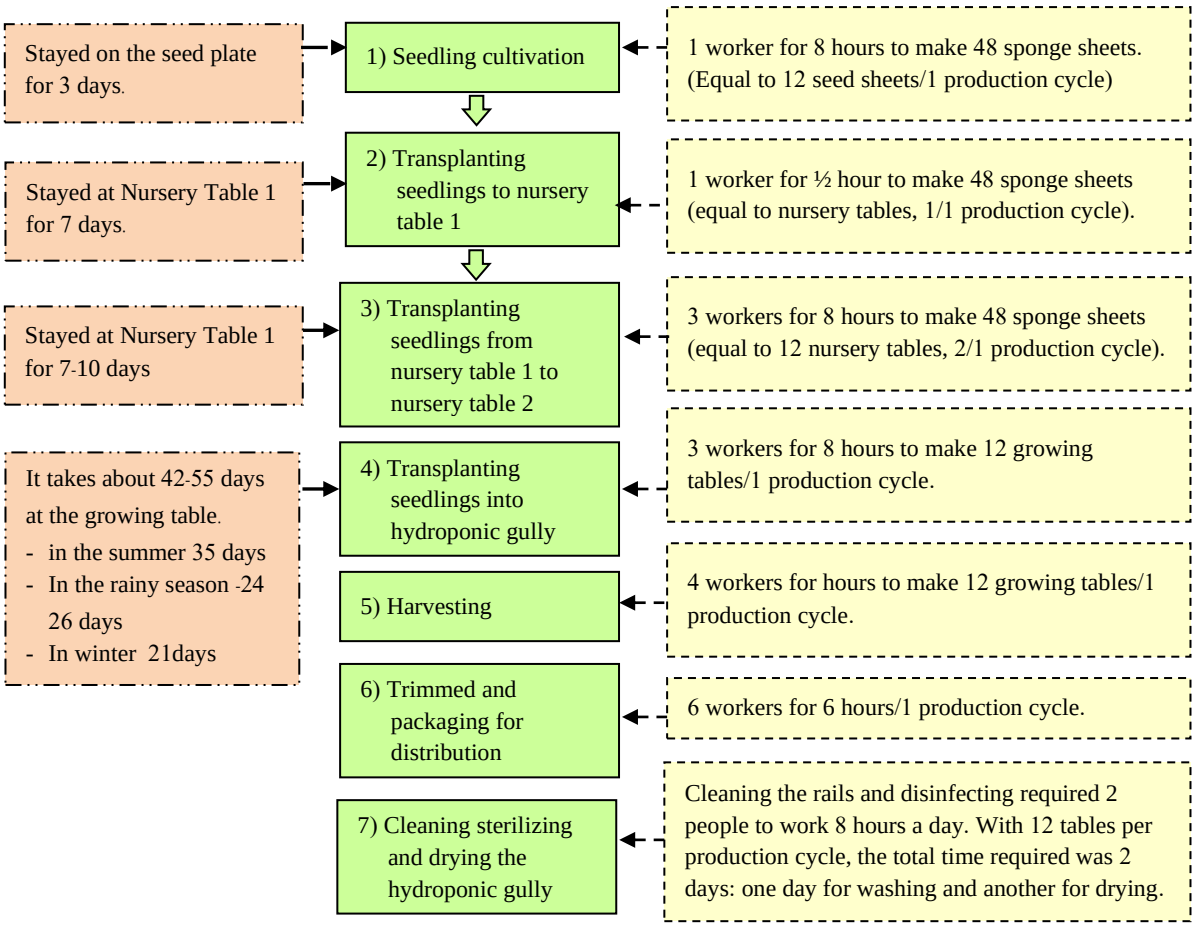
(8) Measure the EC value and add fertilizer A and B every 3 days, maintaining it between 1200-1600. Ensure that the pH value (acidity-alkalinity) remains between 5.5 - 6.5 to adjust it to the most appropriate value for plants, approximately 6.5. Use pH Down (nitric acid + phosphoric acid, 10% concentration) at a ratio of 2 cc per 1 liter of water to adjust the pH value.

(9) Three - seven days before harvesting vegetables, refrain from adding fertilizer and circulate the water in the planting trough. This helped reduce the nitrate levels in the vegetables. Elevated nitrate content within vegetables posed a potential health hazard to consumers, particularly when consumed in significant quantities.

5) Harvesting 12 tables of salad required 4 people and took approximately 2 hours. The harvesting method involved pulling out the planting cup along with the salad plants and placing them in a basket. It was crucial to harvest the salad vegetables in the morning only to prevent the leaves from high temperature, which was able to result in a bitter taste. Harvesting was carried out between 8:00 a.m. and 10:00 a.m., after which the vegetables were immediately trimmed and packed.

6) Trimming packaging for distribution required 6 people and took 6 hours. It was done immediately after harvesting between 10:00 a.m. - 5:00 p.m., including lunchtime. The pruning method involves cutting off the dead leaves, arranging them into beautiful bouquets, rolling up the roots neatly, and packing them into plastic bags. Each bag weighed approximately 1 kilogram. The packaged salad vegetables were then stored in a refrigerator at a temperature of 10-15°C. This ensured that the salad vegetable products were ready to be shipped for sale.

7) Cleaning sterilizing and drying the hydroponic gully for the next production cycle required 2 people, and it took 30-45 minutes per table. Typically, workers finished 12 tables in 1 day, thus requiring 2 people for the activity. One day was allocated for washing and disinfecting the rails, and another day was allocated for drying the rails.



Picture 1: Salad production process of Suan La-or Co., Ltd.

Problematic Factors Affecting Salad Vegetable Production at Suan La-or Company Limited.

Problems, causes, and solutions in producing salad vegetables during the summer were as follows.

1) Root rot and basal rot were caused by high water temperatures during the summer, leading to damage to the plant roots. This damage created an environment where pathogens was able to destroy plant cells. To mitigate this issue, added 200 ml of Trichoderma per 200 liters of water.

2) Vegetables failed to grow due to low oxygen levels in the water. Incorporating a high-oxygen water circulation system within the trough could be a viable solution to this problem. This could be achieved by adjusting the water tank level to a lower position, allowing for more distance between the water flowing from the chute into the water tank. This adjustment promoted increased oxygenation of the water.

3) Vegetables wilted due to the high-temperature environment during the summer season. Incorporating a system for evaporative cooling, which leverages the latent heat of vaporization to produce cool air, could be a viable strategy to address the thermal challenges surrounding the plot. Additionally, jars could be adapted for use as containers to collect water for circulation in the trough. These jars can be buried in the ground using sand to fill around them, helping to reduce the temperature of the water circulated in the trough.

4) Thrips outbreaks were controlled by using tobacco leaf herbal juice or Actara. Four to five grams of Actara were used per 20 liters of water to eliminate thrips during outbreaks.

The problems, causes, and solutions encountered during the production of salad vegetables in the rainy season were as follows:

1) Stretched vegetables were caused by insufficient sunlight for photosynthesis. This was addressed by spraying 500 ml of banana fermented water and 500 ml of vinegar per 20 liters of water to enhance photosynthesis efficiency. Additionally, the shade was opened to ensure that the vegetables received sufficient light.

2) Frog eye leaf spots were caused by vegetables being hit by raindrops, resulting in wounds. Subsequently, Cercospora Capsisi bacteria, floating in the air, could infect the vegetables. This issue was most prevalent during hot, humid weather with alternating rain and sunshine. It was addressed by using Larmina (50 grams/20 liters of water) as a biological agent or Propineb (50 grams/20 liters of water) as a chemical treatment, sprayed every 5 days. Alternatively, if the vegetable plot had a plastic roof, it reduced the occurrence of frog eye spots.

Problems, causes, and solutions in producing other salad vegetables were as follows.

1) The outbreak of worms was caused by an infestation of moths. This was addressed by using Set Point at 50 grams per 10 liters of water or fermented tea waste in liquor, with a ratio of three tablespoons of tea waste soaked in white liquor per 20 liters of water, which was sprayed when there was an outbreak of worms.

2) The presence of grasshoppers or other insects was caused by the grass in the vegetable patch, which provided a habitat for these pests. This was addressed by using tea waste fermented in liquor, with a ratio of three tablespoons of tea waste soaked in white liquor per 20 liters of water for spraying. Additionally, the grass was regularly cut and the plot was cleaned to prevent further infestations.

3) Moss was caused by the water used for planting and the planting trough being exposed to sunlight, allowing the moss to grow due to the nutrients present in the trough. This issue was addressed by filtering the water that would be circulated in the planting trough with synthetic fiber, commonly used for filtering aquarium water, before sending it into the water tank and water pump for use. Alternatively, raising minnows or herbivorous fish in a water tank could also help.

4) Water dripping or leaking was caused by silicone not completely filling the rails in various places. To address this issue, leaks were checked, and silicone was used to stop them.

5) The roof was blown off, water was stuck on the roof, or the roof was damaged due to failure to pull the plastic roof tight or heavy rain causing pressure until the roof hung down. This was addressed by always pulling the plastic tight and pushing out any water that was stuck on the roof.

6) The water in the water tank for circulating in the dry planting trough was caused by a leak in the PVC pipe or the planting trough, or water overflowed from the water receiving trough. To fix this, the leak point was identified and plugged. Additionally, the level of the gutter placement was adjusted so that the water in the gutter had an equal amount.

7) A high pH value is not appropriate for the breakdown of nutrients, and plants cannot use it. This issue arises from the water containing other mixed nutrients. To correct this, the pH should be adjusted to a level of 6.3-6.5.

8) Yellow shoots of vegetables were caused by a lack of iron, which resulted in young or top leaves turning yellow. This issue was observed during the summer because iron was not heat-resistant. Exposing the solution tank to sunlight can lead to the breakdown of iron. Another common cause was when the pH of the water is not adjusted, particularly when it was highly alkaline. In such cases, the added iron may precipitate, making it unavailable for plant absorption. This issue could be

corrected by measuring the pH value before adding fertilizer and then adding fertilizer to ensure that the EC value of the fertilizer falls between 1200-1800.

9) Yellowing of leafy vegetables was caused by a lack of nitrogen. Older leaves on the underside of the plant turned yellow or faded green, while young leaves remained greener. Consequently, the plant grew slowly or stopped growing. To correct this issue, the pH value was measured before adding fertilizer, and then the fertilizer application was adjusted to ensure that the EC value of the fertilizer fell between 1200-1800.

10) Snails ate the vegetable leaves due to the high humidity in the vegetable plot and the presence of grass providing a habitat for snails. This was resolved by eliminating weeds, snail habitats, and sprinkling tea waste or using biological insect repellents to control pests around the table.

With the implementation of the aforementioned process methods, Suan Laor Company Limited successfully produced high-quality vegetables that meet consumer preferences: fresh, crisp, and non-bitter, at a competitive cost. The production costs for each variety of salad vegetables were as follows: Red Oak - 23.77 baht per kilogram, Frillice Iceberg - 23.14 baht per kilogram, Green Oak - 17.12 baht per kilogram, and the overall production cost is 15.51 baht per kilogram. These salad vegetables were sold at an average price of 84.11 baht per kilogram. From this selling price, the company achieved the following net profits: Cos: 32.53 baht per kilogram, Green Oak: 29.53 baht per kilogram, Red Oak: 26.90 baht per kilogram, Frillice Iceberg: 20.62 baht per kilogram. The average profit margin is 32.57 percent, demonstrating the company's efficient commercial hydroponic vegetable production.

Discussion

A study of the salad vegetable growing process at Suan La-or Co., Ltd. revealed the production costs for each variety of salad vegetables: Red Oak had a production cost of 23.77 baht per kilogram, Filley Iceberg cost 23.14 baht per kilogram, Green Oak cost 17.12 baht per kilogram, and the overall production cost was 15.51 baht per kilogram. The factor that affected the cost of each type of salad vegetable was the different labor costs for the operation. This is because each type of vegetable requires different activities, it results in varying labor and wage costs. These varying costs resulted in different net profits. Cos had the highest net profit of 32.53 baht per kilogram, followed by Green Oak with a net profit of 29.53 baht per kilogram, Red Oak with a net profit of 26.90 baht per kilogram, and Frillice Iceberg with a net profit of 20.62 baht per kilogram. Cos achieved the highest net profit because it had the lowest production costs. Moreover, effective vegetable production management led to cost reduction and increased profits.

Conclusion

From the study, it has been found that Suan La-or Company Limited has well-established processes and procedures for growing salad vegetables using the hydroponic method. It can serve as a model for those interested in commercial vegetable production, especially in the northern region where unfavorable weather conditions pose challenges for salad vegetable growth. Particularly during winter, when there is a significant temperature difference between day and night, and in summer, when temperatures are high. Additionally, in salad vegetable production, diseases and insects are common issues. Problems most commonly encountered in summer include root rot, stunted vegetable growth, and wilting, while during the rainy season, vegetables tend to stretch, and dry spots appear on the leaves. Without proper management, this can lead to high production costs and inferior vegetable quality, failing to meet consumer needs. Therefore, salad vegetable production requires careful attention and good practices to ensure high-quality vegetables and competitive production costs. In the salad vegetable production operations of Suan La-or Company Limited, it has been observed that vegetable production is efficient. Each type of salad vegetable has the following costs: Red Oak has a production cost of 23.77 baht per kilogram, Frillice Iceberg costs 23.14 baht per kilogram, Green Oak costs 17.12 baht per kilogram, and the overall production cost is 15.51 baht per kilogram. The company sells vegetables at an average price of 84.11 baht throughout the year. When the average selling price is used to calculate net profit, the company's net profits from selling each type of vegetable are as follows: Cos has the highest net profit of 32.53 baht per kilogram, followed by Green Oak with a net profit of 29.53 baht per kilogram, Red Oak has a net profit of 26.90 baht per kilogram, and Frillice Iceberg net has a profit of 20.62 baht per kilogram. The company maintains an average profit rate of 32.57 percent.

References

Angyureekul, N. (2004). *Agribusiness management.* Department of Agricultural and Resource Economics. Faculty of Economics. Kasetsart University.

Khumpu, T. (1999). *Study of quality and production cost of celery and 4 types of salad vegetables under controlled environment in plant nutrient solution.* School of Bioresources and Technology. King Mongkut's University of Technology Thonburi.

Kim, M. J., Moon, Y., Tou, J. C., Mouand, B., & Waterland, N. L. (2016). Nutritional value, bioactive compounds and health benefits of lettuce (Lactuca sativaL.). *Journal of Food Composition and Analysis, 49,* 19-34.

Phulkerd, S., Gray R. S., & Chamratrithirong, A. (2020). The influence of co-residential and non-co-residential living arrangements on sufficient fruit and vegetable consumption in the aging population in Thailand. *BMC Geriatrics*, *20*(1), 1-8.

Rasameeted, B. (2007). *The supply chain modeling of pesticide free agriculture products in the Thai multinational supermarket.* Lecture Document of Advanced Production Management subject Master's Program for Executives. Kasetsart University.

Sangjaruswong, N. (2005). *A study of factors affecting the consumption behavior of hydroponic vegetables of people in Bangkok* [Master's Independent study]. Kasetsart University.

Suttiprasit, N. (2015). *Feasibility on investment of hydroponic vegetable business* [Master of Business Administration Program]. Silpakorn University.

Thongaram, D. (2004). *Soilless growing: Principles of production management and business production technology in Thailand* (2nd ed.). Pimdee Printing.

Thongaram, D. (2007). *Soilless growing: Principles of production management and business production technology in Thailand* (3rd ed.). Pimdee Printing.

THE ROLE OF AGRICULTURAL DRONE IN AGRICULTURE 4.0 : APPLICATIONS REVIEW

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Abstract

Agriculture is an important key factor for decreasing poverty and improving food security of mankind. Since Agriculture 4.0 was introduced in Thailand, farmers started to change their ways of farm practices from traditional agriculture to modern agriculture. Agricultural drones were one of many modern technologies that had been developed during the age of Agriculture 4.0 and had been promoted around Thailand since 2016 based on the aims of Thailand 4.0 policy. It was greatly adopted by farmers according to the fact that agricultural drones can assist them to solve the labor shortage, reduce production cost and enhance the efficiency of farm management. Generally, aerodynamic features were utilized to categorize types of drones into three types as fixed wing, rotary wing and hybrid. Most agricultural drones in Thailand were employed for crop spraying especially in rice and sugarcane production according to the easiness of operation compared to dense canopy tree. Besides spraying, crops monitoring and broadcasting of seeds and granular fertilizer were gained popularity for farming. Since applications of agricultural drone do have more potential for agriculture sector, further research and development still needed to cover more application criteria and encourage the farmers' adoption.

Keywords: Agricultural Drone, Crop Spraying, Crop Monitoring, Broadcasting, Agriculture 4.0

Introduction

Agriculture is the most important economic sectors in Thailand. It accounted for 9.0% of national GDP in 2023 (World Bank, 2023). In the year of 2023, total agricultural area was about 22.8 million hectares that accounted for almost 44.5 percent of the total area in Thailand (National Statistical Office, 2023) and 12.33 million workers involved in agriculture sector (National Statistical Office, 2024). Since Thailand 4.0 policy was promoted by the Thai government to pull the country out of the middle-income trap, Thailand has attempted to become a major producer of agricultural products over many years. Thai farmers were encouraged to change from traditional agriculture to industrial agriculture. Therefore, new crop varieties, nutrient-rich fertilizers and modern agricultural machineries to improve product qualities, farm productivities and crop yields were introduced to the farmers and well adopted by them (Thailand Board of Investment, 2020).

Since agriculture represents the primary largest food source of the world, it is quite challenging and concerns issues for agricultural producing countries around the world to supply the food to 9.7 billion people by 2050. An increase in food demand results in usage of water that is one of crucial inputs for agriculture in terms of supporting a broad range of activities such as irrigation, watering and cleaning of livestock and aquaculture. Generally, agriculture accounts for around 70% of

water used in the world and contributes to water pollution from excess nutrients, pesticides and other pollutants (Friha et al, 2021). Sustainable management of water in agriculture is critical to increase agricultural production. Therefore, it is important to produce enough food to support people and intensively concerns about the environment especially water usage.

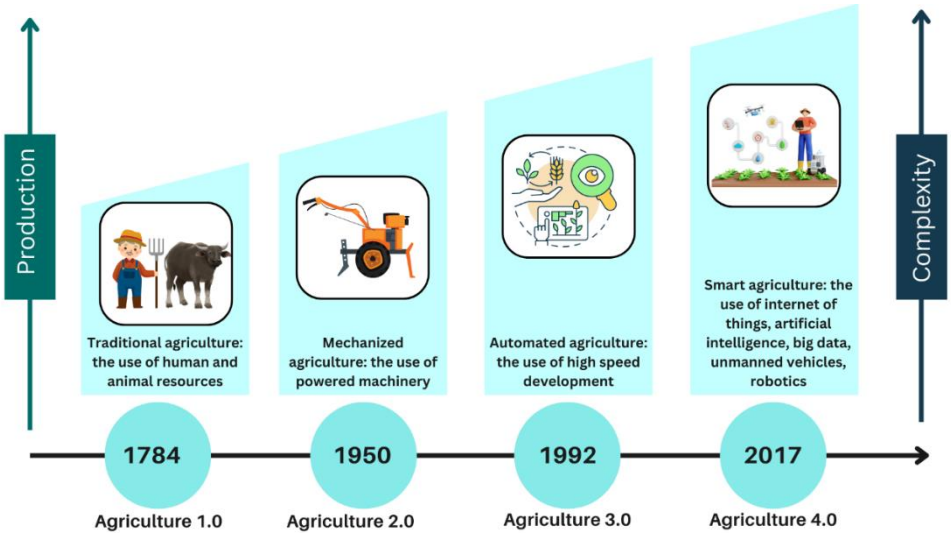
Over many years, agriculture has undergone many revolutions and is illustrated as shown in Picture 1. In general, agricultural revolution could be named into four distinct revolutions. Agricultural revolution began with Agriculture 1.0 that is the traditional farming from the ancient times, where farmers heavily used hand tools such as hoe, sickle and pitchfork for cultivation. The farm practices required a great deal of human labor and animal power. However, farm productivity of this age was very low. Then, Agriculture 2.0 was started at the beginning of the 20th century according to the influence of the first industrial revolution (Industry 1.0). Agricultural machinery was introduced for seedbed preparation, sowing, irrigation, weeding and harvesting. Mechanized agriculture greatly increased farm productivity and decreased human labor and animal power. During the second industrial revolution (Industry 2.0) that took place in the 20th century steam that was the main energy source was replaced by steam. Agricultural products and food could be shipped to further distance. Consequently, new agricultural markets were established for farmers by connecting the isolated communities together. Moreover, embedded systems, software engineering and communication technologies were developed and led to the third industrial revolution (Industry 3.0) that improved the automation capability of manufacturing equipment. New green renewable energy was explored such as photovoltaic power, hydroelectricity and wind power. These above-mentioned developed technologies brought the new agricultural revolution, so-called Agriculture 3.0, which intended to exploring information technologies for precision agriculture through yield monitoring, variable rate technologies (VRT) and guidance farming systems. Then, the Agriculture 4.0 is directly driven by a fusion of emerging technologies from the fourth industrial revolution (Industry 4.0) such as the Internet of Things (IoT), robotics, bigdata, artificial intelligence (AI) and blockchain technology and becomes a smarter and more efficient age that uses the emerging technologies to benefit various applications domains as shown in Picture 2 (Sadiku, et al., 2021; Liu et al., 2021; Huang et al., 2020; Zambon et al., 2019).

Based on Thailand 4.0 policy, Agriculture 4.0 that represents the fourth agricultural revolution that uses digital technologies and moves toward a smarter, more efficient, environmentally responsible agriculture sector (Javaid et al., 2022). Agriculture 4.0 is prioritized to develop particularly agricultural robotics, biotechnology and precision agriculture (PA) or precision farming (Paopongsakorn and Chokesomritpol, 2017). Precision agriculture is a modern farming management concept using various digital techniques to monitor and optimize agricultural production processes. It can optimize amounts of inputs such as water, energy, fertilizers and pesticides by measuring the conditions of the field. Then, the proper amounts of inputs would be applied related to the field conditions instead of applying the same amount of input for an entire field (Sreewongchai & Nakasathien, 2019).

In recent years, unmanned aerial vehicles (UAV) or drones are one of the most broadly applied in various industries including agriculture. Agricultural drones have been dramatically increased and adopted by Thai farmers according to their applications that are capable to solve the labor shortage, reduce production cost and improve the efficiency of farm management (Chantharat and Maikaensarn, 2020). Furthermore, agricultural drones are considered as agricultural machineries that are easy to use and affordable even if for small-scale farmer (Thailand Board of Investment, 2020).

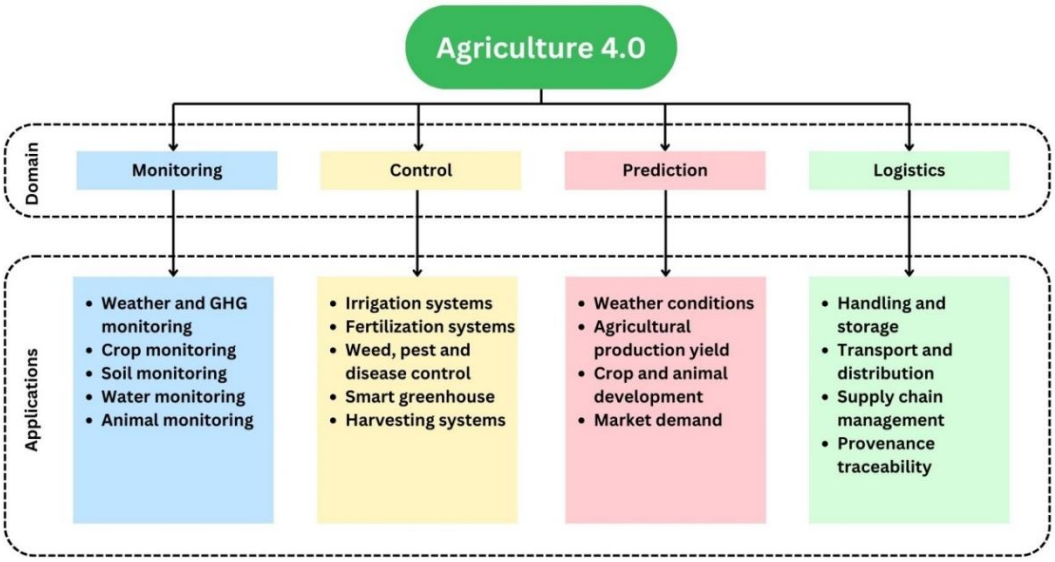
According to the above research, agricultural drones had played a significant role in Agriculture 4.0 and Thailand 4.0 policy. Therefore, this review article intended to summarize the fundamental knowledge about the agricultural drone and applicability in agriculture. The contributions of this work are as follows:

- The development history and types of agricultural drone were introduced in detail and is sorted into a timeline. It is easy for readers to understand how agricultural drones were developed.
- The application of agricultural drone in Thailand that especially emphasized in crop spraying, crop monitoring and broadcasting of seed and fertilizer.



Picture 1: Four agricultural revolutions

Source: Modified from Friha et al., 2021



Picture 2: Four agricultural revolutions

Source: Sadiku et al., 2021

Unmanned aerial vehicles in agriculture

Unmanned aerial vehicle (UAV) or remotely piloted aircraft (RPA) is an uncrewed aircraft which can fly without a pilot and can be controlled by using a radio channel by an operator (He et al., 2017; Radoglou-Grammatikis et al. 2020). The first attempts to develop UAV were initiated for military purposes starting with the First World War (WWI) by Dayton-Wright Airplane Company that invented an aerial torpedo which was able to be exploded at a preset time (Gonzalez-Jorge et al., 2017). Currently, approximately 85 % of drone technology is mainly developed by the military and the rest of 15% by civilians for various applications (Puri et al., 2017). Besides the fact that the first drone came from the military world, many UAVs were also developed to serve in civilian applications. The novel technologies such as global navigation satellite system (GNSS), inertial measurement unit (IMU), electronic speed controllers (ESC) for brushless motors, lithium Polymer batteries and digital imaging system are affordable and accessible for drone developer (Gonzalez-Jorge et al., 2017).

For agriculture, the first UAV model was developed by Yamaha as unmaned helicopter Yamaha model RMAX for agricultural pest control and crop monitoring (Mogili and Deepak, 2018). In the year of 2001, approximately 1,220 units of Yamaha unman helicopter had been sold and used in Japan (Dutta & Goswami, 2020). For Southeast Asia, Thailand was the first country that applied agricultural drones by the introducing from DJI (Chantharat & Maikaensarn, 2020). Then, agricultural drones were bought by farmers and drone service providers for monitoring plant health and crop spraying (Bhandhubanyong and Sirirangsri, 2019). However, most of farmers in Thailand are small-scale farmers whom their farm sizes are around half-hectare (Chantharat & Maikaensarn, 2020). Thus, they may face some difficulties to own agricultural drone by themselves. Therefore, the farmers rely on local agricultural drone service providers and hire them for crop spraying. Besides crop spraying, agricultural drones are also applied for seed sowing, fertilizer spraying and field surveying (Chantharat & Maikaensarn, 2020). Number of farmers who adopted the agricultural drone technology has dramatically increased due to the promising application. According to the growth of agricultural drone market, it had been projected that it is expected to expand around 200 % or 30,000 units of agricultural drone in 2028 (Thansettakij, 2023).

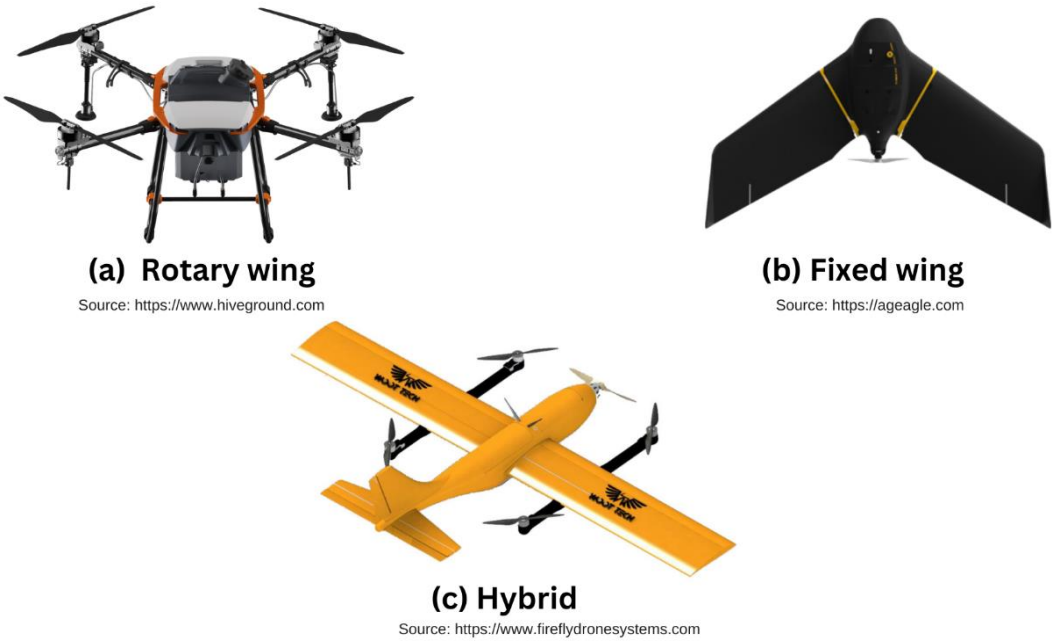
Type of unmanned aerial vehicles

Generally, UAV often classifies by using various criteria as shown in Table 1. The most frequent criteria that is utilized to identify the class or characteristic of UAV is the aerodynamic features. Fixed wings, rotary wing and hybrid drone were respectively illustrated as in Picture 3 (a), (b) and (c).

Table 1: Criteria and types of UAV

Literature work	Criteria	types of UAV
Watt et al. (2012)	size, flight endurance and capacities	• MAVs (Micro or Miniature Air Vehicles) • NAVs (Nano Air Vehicles) • VTOL (Vertical Take-Off & Landing), • LASE (Low Altitude, Short-Endurance), • LASE Close • LALE (Low Altitude, Long Endurance), • MALE (Medium Altitude, Long Endurance), • HALE (High Altitude, Long Endurance)

Literature work	Criteria	types of UAV
Radoglou-Grammatikis et al. (2020)	aerodynamic features	• Fixed wing • Rotary wing • Hybrid
Mukherjee et al. (2019)	aerodynamic features	• Fixed wing • Wingless • Bio-mimicry
Mogoli et al. (2018)	number of rotors	• Fixed wing • Single rotor • Quad copter • Hexa copter • Octa copter



Picture 3: Types of drones categorized using aerodynamic features

Applications of agricultural drone

Crop spraying

In Thailand, agricultural drones are commonly applied for spraying pesticides, herbicide, plant hormone and fertilizer according to superior effectiveness compared to conventional spraying method in various crops. The application for crop spraying of agricultural drone in Thailand has significantly increased according to rapid adoption from farmers (Soyyana, Chaovanapoonphol & Saeliw, 2022; Wajasuwan & Wongsansukcharoen, 2021). Sreewongchai & Nakasathien (2019) and (He et al., 2017) described the advantages of spraying by agricultural drones as follows.

(1) Drone does not require any dedicated airport and navigation station and it can land on the edge of cultivation land.

(2) Short turning radius of drone could help it hover and turn round flexibly in the air.

(3) High rate of climb of drone could help it to fly vertically and have good performance of super low flight.

(4) Low rate of no-load flight of drone and filling fuel and liquid on the ground of working area could reduce invalid working time.

(5) Drone is suitable for working in rough terrain and small plots with high efficiency and operates with high automaticity, less flight crew, low labor intensity and simple to use and maintain in comparison with traditional manned aircraft.

(6) Drone provides a very high degree of atomization that can be pressed to all levels of crop and can spray pesticides with a fixed position and fixed orientation while reducing the pollution to water and soil.

(7) Farmers can reduce the risk from pesticide exposure and heatstroke incidents.

(8) An ultra-low volume spraying can reduce water usage in agriculture.

For rice production especially in central plain of Thailand, agricultural drones were intensively employed for pre-emergence and post-emergence chemical spraying. Research by Kamthonsiriwimol et al., (2020) indicated that agricultural drones could spray more uniformly droplet without significant difference of concentration of droplet deposition compared to knapsack sprayer in paddy field. Furthermore, a survey by Chantharat & Maikaensarn (2020) reported that agricultural drone can increase the productivity of rice by 15% and reduce chemical by 35%.

To boost up the sugarcane production in Thailand, agricultural drone was utilized to spray the hormone fertilizer on sugarcane canopy for improving sugar content. An increase in commercial cane sugar (CCS) can be done up by applying the hormone fertilizer when the age of plants does not exceed eight months old (Koondee et al., 2019).

Besides rice and sugarcane, agricultural drone had been employed for canopy trees. It was applied for controlling coconut beetle weevil for the coconut growers in the southern of Thailand. Spraying in coconut plantation quite differs from paddy field according to the nature of the tall coconut trees as well as the level of wind speed in the coastal areas. The results indicated that it could save the pesticide by 20-25%. This is the great evident of advantages of crop spraying by using agricultural drone (Daoden et al. 2021). However, agricultural drone is difficult to spray in very dense canopy crops such as durian. Research by Thongnim et al. (2023) revealed that the top of the canopy has more effective droplet covering than the middle and bottom of the canopy. In their findings, further research related to nozzle size and suitable operation conditions and procedures were still required to determine the appropriate spraying practice for agricultural drones.

Crop monitoring

Routine monitoring of crops is usually performed by farmers to detect the conditions of crops including disease, pests and rate of growth. Farmers need to go to the fields and visually inspect the crops in traditional method. During age of Agriculture 4.0, various types of cameras such as RGB camera, multispectral camera, thermal camera and hyperspectral camera were developed and mounted on the agricultural drone to monitor crops in the field (Choros, Oberski & Kogut, 2020; Raeva, Sedina &Dlesk,2018; Choosumrong et al., 2023; Messina & Modica, 2020). Thermal camera usually equipped with infrared sensor can provide a thermal map that contains the temperature data of crop. RGB images from RGB camera can be processed to extract red-green-blue color information while multispectral and hyperspectral camera can capture both visible and invisible images of the crops with specific wavelengths. Normalized difference vegetative index or NDVI is often applied to indicate the condition of crops. Multispectral and hyperspectral cameras can provide the data based on the following equation,

$$\text{Normalized difference vegetative index } (NDVI) = \frac{NIR-RED}{NIR+RED} \quad (1)$$

Where NIR is the reflection in the near-infrared spectrum and RED is the reflection in the red range of spectrum (Ghazali, Azmin & Rahiman,2022).

In Thailand, crops conditions by using agricultural drone has been intensively developed for field crops and fruits.For banana plants, a multispectral camera was implemented to capture multispectral images by using an agricultural drone with Real-time kinematic (RTK) positioning. The assessment was done to determine the health and growth of banana plants by flying at a height of 80 m. Triangular Vegetation Index (TVI), Normalized Difference Red Edge Index (NDRE) and Normalized Difference Vegetation Index (NDVI) were employed to monitor the banana plants. The results indicated that the accuracy of plants health assessment was over 88.0% (Choosumrong et al., 2023). Besides banana plants, a system for measuring plant health and bacterial infection was developed in rice by using images from agricultural drones. Convolution neural network was applied to detect bacterial infection. The results revealed that developed classification techniques could be utilized to classify the types of rice deceases with an accuracy rate of 89.84 percent (Prasomphan, 2023).

Broadcasting

Recently, agricultural drones have been utilized for seed sowing and fertilization. An attachment device as illustrated in Picture 4 would be equipped to the drone for broadcasting both fertilizer and seeds. Rotary wing drone is the most popular type of drone that generally applies for broadcasting because the possibility of drone to stay in the air motionless or to move in any direction with the speed independent on the height level and load of the performed work (Boguslawa,2020). Air broadcasting of rice is throwing a certain amount of rice seeds directly into the well-tilled paddy field. The better spreading of seeds and the larger coverage area in a quick time could obtained over manual spreading for sowing of rice seeds with the help of drones (Vijayakumar et al., 2022). It would be the alternative reduction of labor input and improvement of productivity (Li et al., 2016).

Since traditional fertilizer broadcasting involves manually spreading fertilizer over the surface of the field, it may be a trigger of insufficient or oversufficient of fertilizer. The exceeded use of fertilizer is considered as one of main causes of environmental crisis. For the greatest fertilizer use efficiency, split application of fertilizer at the right timing was recommended to the farmers. However, it seems to be a challenge for them because more requirement of labor for fertilizer application are needed while labor shortage is very severe in the agriculture sector. Thus, agricultural drones may be the best option for them to reduce the labor requirement (Vijayakumar et al., 2022). For broadcasting of fertilizer, the use of drones to spread fertilizers can increase production yields and reduce the tiresome process (Nuryadi et al., 2021).

Picture 4: Attachment device for broadcasting system of agricultural drone

Source: https://ag.dji.com

Conclusions

Agricultural revolution plays important roles in the development in agriculture of many countries around the world. To enable Thailand to escape from the middle-income trap, the Thailand 4.0 policy was launched. Based on Thailand 4.0 policy, many emerging agricultural technologies were introduced in Thailand including agricultural drone that gained very high acceptances from the farmers. Number of agricultural drones in Thailand tended to be dramatically increased since 2016. The predominant use of agricultural drones is crops spraying, crop monitoring and broadcasting. An acceptance of spraying using agricultural drone quite great in field crops according to the easiness of drone operation. However, it seems to be difficult when compared to dense canopy of trees in the orchards such as durian. For crop monitoring, various types of cameras were developed during the age of Agriculture 4.0. The images of crops were captured by camera that mounted on the agricultural drone and were analyzed to monitor the conditions of the crops. For broadcasting seeds and fertilizers, the attachment device was developed to the agricultural drone. The promising results of broadcasting were evidently noted for reducing the severity of labor shortage and increasing productivity and yields. Therefore, it is such a great challenge for agricultural drones to apply in agriculture and assist Thailand to break through Agriculture 4.0.

References

Bhandhubanyong, P., & Sirirangsi, P. (2019). The development of agricultural tools in Thailand: Case studies of rice and maize. *New Trends and Challenges for Agriculture in the Mekong Region: From Food Security to Development of Agri-Businesses*. Retrieved April, 25, 2024, from https://www.ide.go.jp/library/English/Publish/Download/Brc/pdf/25_03.pdf

Boguslawa, B. (2020). Fertilization and sowing from unmanned aerial vehicles. *Polish Technical Review, 2*, 18-22.

Chantharat, M., & Maikaensarn, V. (2020). Application of drone used for rice production in Central Thailand. *Proceedings of PIM 10th National and 3rd International Conference 2020* (pp. 904-910). Panyapiwat Institute of Management.

Choosumrong,S., Hataitara, R., Sujipuli, K., Weerawatanakorn, M., Preechaharn, A., Premjet, D., Laywisadkul, S., Raghavan, V., & Panumonwatee, G. (2023). *Spatial Information Research, 31*, 371-380.

Choros, T., Oberski, T., & Kogut, T. (2020). *UAV imaging at RGB for crop condition monitoring. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* Retrieved May, 17, 2024, from https://isprs-archives.copernicus.org/articles/XLIII-B3-2020/1521/2020/isprs-archives-XLIII-B3-2020-1521-2020.pdf

Daoeden, K., Sornnen, T., Pankasemsuk, T., Phahuangwittayakal, P., Srigamn S., & Nicrotha, S. (2021). Development of agricultural spraying drones prototype for coconut beetle weevil control. *Natural Volatiles & Essential Oils, 8*(5), 8322-8322.

Dutta, G., & Goswami, P. (2020). Application of drone in agriculture: A review. *International Journal of Chemical Studies, 8*(5), 181-187.

Friha, O., Ferrag, M.A., Shu, L., Maglara, L., &Wang, X. (2021). Internet of thing for future of smart agriculture: a comprehensive survey of emerging technologies. *IEEE/CAA Journal of Automatica Sinica SINICA, 8*(4), 718-752.

Ghazali, M.H.M, Azmin, A., & Rahiman, W. (2022). Drone implementation in precision agriculture-a survey. *International Journal of Emerging Technology and Advanced Engineering, 12(4),* 67-77.

Gonzalez-Jorge, H., Martinez-Sanchez, J., Bueno, M., & Arias, Pedor. (2017). Unmanned aerial systems for civil applications: a review. *Drones, 1*(2), 1-19.

He, X., Bonds, J., Herbst, A. & Langenakens. (2017). Recent development of unmanned aerial vehicle for plant protection in East Asia. *International Journal of Agricultural and Biological Engineering, 10*(3), 18-30.

Huang, K., Shu, L., Li, K., Yang, F., Han, G., Wang, X., & Pearson, S. (2020). Photovoltaic Agricultural internet of things towards realizing the next generation of smart farming. *IEEE Access, 8,* 76300-76312.

Javaid, M., Haleem, A., Sigh, R.P., & Suman, R. (2022). Enhanching smart farming through the applications of Agriculture 4.0 technologies. *International Journal of Intelligent Networks, 3,* 150-164.

Kamthonsiriwimol, N., Punyawattoe, P., Hungiang, D., Hasegawa, H., Pibanthan, M., & Li, X. (2020). Evaluation of the spraying deposition and spraying drift by using unmanned aerial vehicles (UAV) in paddy field. *Proceedings of PIM 10th National and 3rd International Conference 2020* (pp. 924-936). Panyapiwat Institute of Management.

Li,J., Lan,Y., Zhou,Z.,Zen,S., Huang,C.,Yao,W., Zhang,Y., & Zhu, Q. (2016).Design and test of operation parameters for rice air broadcasting by unmanned aerial vehicle. *International Journal of Agricultural and Biological Engineering, 9(5),* 24-32.

Liu, Y., Ma, X., Shu, L., Hancke, G.P., & Abu-Mahfouz, A.M. (2021). From industry 4.0 to agriculture 4.0: current status, enabling technologies, and research challenges. *IEEE Transactions on Industrial Informatics, 17*(6), 4322-4334.

Maikaensarn, V., & Chantharat, M. (2019). *Effectiveness analysis of drone use for rice production in central Thailand.* New Trends and Challenges for Agriculture in the Mekong Region: From Food Security to Development of Agri-Businesses. Retrieved April, 25, 2020, from https://www.ide.go.jp/library/English/Publish/Download/Brc/pdf/27_05.pdf.

Messina, G., & Modica, G. (2020). Application of UAV thermal imagery in precision agriculture: state of the art and future research outlook. *Remote Sensing, 14,* doi:10.3390/rs12091491.

Mogili, U.R., & Deepak, B.B.V.L. (2018). Review on application of drone system in precision agriculture. *Procedia Computer Science, 133,* 502-509.

Mukherjee, A., Misra, S., & Raghuwanshi, N.S. (2019). A survey of unmanned aerial sensing solutions in precision agriculture. *Journal of Network and Computer Applications, 148,* 102461.

National Statistical Office. (2023). 2023 *Agricultural census.* Retrieved April, 10, 2024, from https://www.nso.go.th/nsoweb/storage/upload_file/2024/20240111123314_35658.pdf [in Thai]

National Statistical Office. (2024). *The labor force survey.* Retrieved April, 10, 2024, from https://www.nso.go.th/nsoweb/nso/survey_detail/9u [in Thai]

Nuryadi, S., Mardhiyyah, R., Pratama, B., & Zulkhairi, J. (2021). Hexacopter drones for fertilizer sowing in the agriculture sector using the global positioning system (GPS). *International Journal of Engineering, Technologyand Natural Sciences, 3*(2), 39-46.

Paopongsakor, N., & Chokesomritpol, P. *Agriculture 4.0: Obstacles and how to break through.* Retrieved April, 15, 2024, from https://tdri.or.th/en/2017/06/agriculture-4-0-obstacles-break-2

Prasomphan, S. (2023). Rice bacterial infection detection using ensemble technique on unmanned Aerial vehicles images. *Computer Systems Science and Engineering, 44*(2), 991-1007.

Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: a modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems, 20*(4), 507-518.

Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T., & Moscholios. (2020). A compilation of UAV applications for precision agriculture. *Computer Networks, 172,* 107148.

Raeva, P.L., Sedina, J., & Dlesk, A. (2018). Monitoring of crop fields using multispectral and Thermal imagery from UAV. *European Journal of Remote Sensing, 52*(1), 192-201.

S Vijayakumar,S., Madireddy,H., Bhusarapu,S.C., Kumar, R. M., & Sundaram R. M. (2022). Drone application in rice cultivation: experiences from ICAR-IIRR trails. *Indian Farming, 72*(12), 3-6.

Sadiku, M.N.O., Chukwu, U.C., Ajayi-Majebi, A., & Musa, S.M. (2021). Introduction to agriculture 4.0. *Journal of Scientific and Engineering Research, 8*(4), 121-128.

Soyyana, A., Chaovanapoonphol, Y., & Saeliw, K. (2022). Farmer's adoption of drone technology for spraying chemicals in Sankamphaeng district, Chiang Mai province. *Khon Kaen Agriculture Journal, 1,* 385-391.

Sreewongchai, T., & Nakasathien, S. (2019). *Precision agriculture for rice production in Thailand.* Retrieved March, 15, 2024, from https://ap.fftc.org.tw/user/login?destination=system/files/field/file/article/1007_1.pdf

Thailand Board of Investment. (2020). *Farmnovation technology in the field.* Retrieved April, 5, 2024, from https://www.boi.go.th/upload/content/TIR7_Aw_Smart%20farming_5e5dc88fa8284.pdf

Thansettakij. (2023). *Thai farmers armed with digital weapons to wake up 200% drone market growth.* Retrieved April, 8, 2024, from https://www.thansettakij.com/technology/technology/581139

thermal imagery from UAV. European Journal of Remote Sensing, DOI: 10.1080/22797254.2018. 1527661

Thongnim, P, Yuvanatemiya, V., Charoenwanit, E., & Srinil, P. (2023). Design and testing of spraying drones on durian farms. *Proceedings of 2023 International Technical Conference on Circuits/Systems, Computers, and Communications (ITC-CSCC)* (pp. 1-6). IEEE.

Wajasuwan, T., & Wongsansukcharoen, J. (2021). Acceptance of technology and innovation affecting the intention of using drone for agriculture in the agricultural industry. *Panyapiwat Journal, 14*(1), 143-157.

Watts, A.C., Ambrosia, V.G., & Hinkley, E.A. (2012). Unmanned aircraft systems in remote sensing and scientific research: classification and considerations of use. *Remote Sensing, 4*(6), 1671-1692.

World Bank. (2023). *Thai Economy to Accelerate in 2023 as demand from major economies picks up, tourists return.* Retrieved April, 25, 2024, from https://www.worldbank.org/en/news/press-release/2023/06/28/thai-economy-to-accelerate-in-2023-as-demand-from-major-economies-picks-up-tourists-return

Zambon, H., Cecchini, M., Egidi, G., Saporito, M.G., & Colantoni, A. (2019). Revolution 4.0: Industry vs. agriculture in a future development for SMEs. *Processes, 7*(1), 1-16.