Volume 3, Number 2, July-December 2025 Community University Engagement Journal CUE-J Research Article
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Innovation in closed-system production of Wolffia and development of high-protein commercial products at the community level in Maha Sarakham Province

Supachai Sutticharean, Jindawan Wibuloutai[2], Saowalak Sutticharoen[3], Chuleewan Thunyasirinon[3], Nuchnapa Prathumchai[3] and Kallaya Harnpicharnchai[4]

[1] *Department of Agricultural Technology Faculty of Technology, Mahasarakham University*
[2] *Division of Health Technology and Safety Faculty of Public Health, Mahasarakham University*
[3] *Division of Environmental Health Faculty of Public Health, Mahasarakham University*
[4] *Division of Occupational Health and Safety Faculty of Public Health, Mahasarakham University*

Received: 18 September 2024, **Revised**: 20 November 2024, **Accepted**: 9 January 2025

Abstract - The production and cultivation of watermeal (Wolffia) focuses on developing efficient methods to reduce costs and increase commercial value. This involves using locally sourced materials to construct a prototype farm. The two main species of Wolffia found in Thailand are Wolffia arrhiza and Wolffia globosa, which differ in their physical characteristics and growth patterns. Cultivation is carried out in cement ponds, where water quality is controlled, and plant-based nutrients are used instead of fermented animal manure to reduce the risk of contamination by pathogenic microorganisms such as E. coli and coliforms. The nutrient formula was developed using plant protein and amino acids to accelerate growth, along with the use of seaweed stimulants and enzymes like humic acid, which enhance the efficiency of nutrient absorption. This system development aligns with GAP (Good Agricultural Practices) and organic farming standards to build consumer confidence and prepare for commercial production.

Water quality analysis results of the cultivation water showed that physical and chemical parameters met the standards, except for heavy metals such as cadmium and chromium, which were found to exceed the standard limits due to the use of cow manure fertilizer and seaweed. Furthermore, the quantity of total coliform bacteria exceeded the standard limit in all cultivation water samples. Therefore, Wolffia should be washed multiple times or cooked thoroughly to ensure safety before consumption. In terms of nutritional value, the Wolffia yield cultivated with seaweed fertilizer had higher protein, fat, and crude fiber content than that cultivated with cow manure fertilizer. Harvesting at the appropriate time yields Wolffia with high nutritional value, especially when cultivated for a single harvest. The development

of products and processing of Wolffia to increase commercial value helps generate sustainable income for the community. Examples of developed products include Wolffia ice cream and Wolffia spaghetti noodles. Wolffia ice cream is a homemade green tea ice cream blended with dried roasted Wolffia, containing natural ingredients such as condensed milk, pasteurized fresh milk, and whipping cream, thus increasing its nutritional value, particularly protein and antioxidants. Wolffia spaghetti noodles use dried roasted Wolffia mixed with wheat flour and chicken eggs, enhancing protein and dietary fiber. These products exemplify food innovation that integrates local ingredients with Western cuisine, promoting the use of community resources to increase nutritional value, especially protein and antioxidants.

Keywords: Wolffia cultivation, Wolffia, Wolffia cultivation in a closed system

1. Introduction

Plant protein has received significant attention as an alternative to animal protein because it has a lower environmental impact and can be produced more efficiently than animal protein. It can solve the future problem of insufficient protein food and benefits human health (Prosridee et al., 2023). Watermeal (Wolffia arrhiza (L.) Wmm.), or known locally as “Khai Pham” or “Pham”, is a very small, free-floating aquatic plant in the Lemnaceae family, found in ponds, swamps, or stagnant water sources. It has small, green, round or nearly round grains, with a diameter of 0.5 - 1.5 millimeters, classified as a flowering plant without roots or leaves, and is the smallest plant in the world.

The nutritional composition of watermeal (Wolffia arrhiza (L.) Wmm.) on a fresh weight basis shows: 24.31 % protein, 3.04 % fat, 12.68 % crude fiber, 11.05 % insoluble dietary fiber, 3.82 % soluble dietary fiber, and 14.87 % or 19.97 % total dietary fiber on a dry weight basis. Additionally, it contains 30.17 mg/100g total chlorophyll, 3.43 mg/100g beta-carotene, 0.40 mg/100g riboflavin, and 21.41 mg/g total phenolics on a dry weight basis, with 65.91 % antioxidant activity (by ABTS method) and 70.12 % (by DPPH method) (Niyanuch & Tangwongchai, 2010). Zhubin et al. (2022) studied protein from Wolffia arrhizal 7678a and found 50.89 % protein on a dry weight basis and 0.75 % essential amino acids, with a high proportion of unsaturated fatty acids. Phenolics and total flavonoids are also at high levels compared to other plants, making it a valuable source of antioxidants. These potentials suggest that Wolffia is a suitable food source for humans. Sukhum Raochai and Sutin Somboon (2007) compared the protein content of Wolffia, finding it to be at a similar level to various types of beans and grains, with high fiber content and essential amino acids comparable to chicken eggs, spirulina, and chlorella. Furthermore, the chlorophyll in watermeal has more antioxidants than spirulina, which is used to treat constipation and anemia. Wolffia is therefore an alternative protein source that has a short propagation time, high yield, and low production cost.

Currently, Wolffia is consumed in various forms, such as an ingredient in chocolate muffins (Boonwittaya et al., 2016), watermeal sheets (Deepanya, 2012), noodles supplemented with Wolffia (Kunlaporn Phutthami & Waritchon Ninlanon, 2021), powdered Wolffia protein supplements (Nattanaree Inta, 2022), and Wolffia chewable tablets (Phiphatphong Wongyai et al., 2011).

Wolffia is commonly found naturally in Thailand, particularly in the North and Northeast, in locations such as Khon Kaen, Kalasin, Maha Sarakham, Kamphaeng Phet, Uthai Thani, Lampang, and Chiang Mai. However, due to changing natural environments and shallow water sources, the presence of Wolffia in nature has decreased, along with issues of dirty and polluted natural water sources (Tira-umphon & Nitwatthanakull, 2018). Consequently, Wolffia faces consumer acceptance limitations regarding hygiene and toxic residues (Jutasong, 1999). Therefore, Wolffia production must focus on both quantity and quality to gain consumer trust. Wolffia grows and yields rapidly in a short period; it can yield 2 kilograms after only 6 days of cultivation (Sukhum Raochai & Sutin Somboon, 2007), a yield rarely achieved by other plants in such a short time. There are several forms of Wolffia production for consumption, such as cultivation using hydroponic fertilizers, which results in fast-growing, clean, safe Wolffia without a fishy smell (Damna et al., 2017). Wolffia propagation can occur throughout the year, depending on the water volume in the culture pond. Most Wolffia culture ponds are located in areas covered by large trees, such as rain trees, mango trees, and Pithecellobium dulce. Dry leaves accumulating at the bottom of the pond decompose into organic matter, which serves as a nutrient source for Wolffia. These trees also provide shade to reduce light intensity, as Wolffia grows well in indirect light and propagates better in shaded ponds, resulting in a darker green color than in open-sun ponds (Sukhum Raochai & Sutin Somboon, 2007).

Based on the above information, the researchers selected a prototype community in Maha Sarakham Province. This group of farmers is part of the Khut Rang Sub-district Volunteer Network for the Protection of Natural Resources and Environment. The project is promoted by lecturers from the Faculty of Technology and the Faculty of Public Health, Mahasarakham University, in collaboration with the Maha Sarakham Provincial Office of Natural Resources and Environment (MNRE). The project started with the Khok Nong Na Model, including experimental planting of kitchen vegetables, field crops, and peanuts for sale within the area and nearby community networks. The MNRE allocated agricultural land for the members to experiment with land management under the supervision of the committee, with conditions for production planning, quality control, environmental non-destruction, and conservation, ensuring production for sale throughout the year. This is also to prepare for receiving other production standards, such as GAP and Organic Thailand standards. The Faculty of Technology proposed a concept for managing the area as a prototype area for high-protein plant production with certified standards, quality, safety for consumers, and as a learning center for students and local farmers to study, exchange knowledge, and potentially use this as a supplementary or primary occupation in the future.

2. Objectives

1. To study and develop technology for the production, cultivation, and utilization Wolffia to increase its commercial value.
2. To check for food safety according to GAP (Good Agricultural Practices) guidelines for the production of Wolffia as a food crop.
3. To develop prototype products from Wolffia to increase the value of the yield.

3. Research methodology

This research was conducted between June and September 2024. The target areas were the Khut Rang Sub-district Volunteer Network for the Protection of Natural Resources and Environment in Khut Rang Sub-district, Kut Rang District, Maha Sarakham Province, and the Faculty of Technology Agricultural Farm (Na Si Nuan area), Mahasarakham University. The study focused on innovation in closed-system Wolffia production and the development of high-protein commercial products at the community level in Maha Sarakham Province, aiming to mitigate limitations in the continuity of Wolffia yield, cultivation area size, and food utilization. The research results led to a cultivation method that allows year-round production of Wolffia. A prototype cultivation kit was developed to reduce the cultivation area while controlling environmental conditions suitable for growth, thus creating a new source of high-nutritional food. This is considered a path to promoting high-protein plants like Wolffia as a potential new food source. Increasing the commercial value of the yield at the farm level involves integration and the organization of academic service projects to drive successful implementation, divided into 3 phases as follows:

3.1 Upstream activities

Transfer of technology for the production, cultivation, and utilization of Wolffia to increase its commercial value. This includes efficient and suitable Wolffia cultivation methods and processes for the area. A simple cultivation model was developed to reduce production costs by using materials available in the community, creating a prototype farm for Wolffia cultivation, along with knowledge about the suitable conditions for the cultivation process, enabling expansion to industrial-scale production. The process also ensures safe and high-quality raw materials, ready for commercial expansion and preparation for future GAP standard certification. This utilizes the area within the Faculty of Technology Agricultural Farm (Na Si Nuan area), Mahasarakham University, in collaboration with the Khut Rang Sub-district Volunteer Network for the Protection of Natural Resources and Environment, Khok Nong Na, and sustainable agriculture in Village No. 7, Khut Rang Sub-district, Kut Rang District, Maha Sarakham Province.

3.2 Midstream activities

Transfer of knowledge on food safety and production standards according to GAP (Good Agricultural Practices) for sanitation and traceability. This involves monitoring and surveillance of the quality of agricultural products throughout the supply chain from the Wolffia cultivation process. The goal is to build consumer confidence, improve the quality of life for producers and consumers, ensure safety from toxins and

contaminants, and lead to high-quality, consumer-safe products, aligning with the principles of GAP guidelines from the National Bureau of Agricultural Commodity and Food Standards (ACFS). This covers the upstream, midstream, and downstream production processes, ensuring maximum resource utilization, agricultural sustainability, and minimal environmental pollution.

In Wolffia cultivation, the research team conducted cultivation experiments under 3 different conditions. Water samples were collected from the cultivation ponds to analyze water quality for physical (pH, temperature, turbidity, total dissolved solids), chemical (electrical conductivity, total nitrogen, total phosphorus, heavy metals (cadmium, lead, chromium)), and biological parameters (total coliform bacteria and E. coli). This was to study the suitable conditions and contamination from the use of cow manure fertilizer and seaweed fertilizer in cultivation, as follows:

Condition 1: Natural
Condition 2: With cow manure fertilizer
Condition 3: With seaweed fertilizer

The plan was to collect water and Wolffia yield samples from all 3 conditions at the initial stage before adding fertilizer, the intermediate stage during cultivation with added cow manure and seaweed fertilizer, and the harvesting stage, totaling 3 times:

1st Time: Initial stage (No fertilizer added to the pond)
2nd Time: Intermediate stage of Wolffia cultivation (Cow manure and seaweed fertilizer added to the pond)
3rd Time: Wolffia harvesting stage

3.3 Downstream activities

Transfer of knowledge and technology for increasing the value of the yield from Wolffia cultivation. This involves developing prototype products to meet the continuously growing plant protein market. This growth is driven by changing consumer behavior, increased interest in health, and greater attention to diet, including a reduction in meat consumption and a shift towards plant protein. Plant protein is a suitable choice because it is easily absorbed. “Wolffia” is considered an aquatic plant with outstanding protein benefits, recognized globally as one of the world’s finest superfoods due to its complete and high nutritional profile, including vitamins, minerals, fiber, and protein. Its tiny, spherical shape has earned it the nickname “Green Caviar”. This highlights a market opportunity for product development, offering an alternative for Wolffia farmers and enabling its use as a resource and main occupation. The conceptual framework for the operational steps is shown in Figure 1.

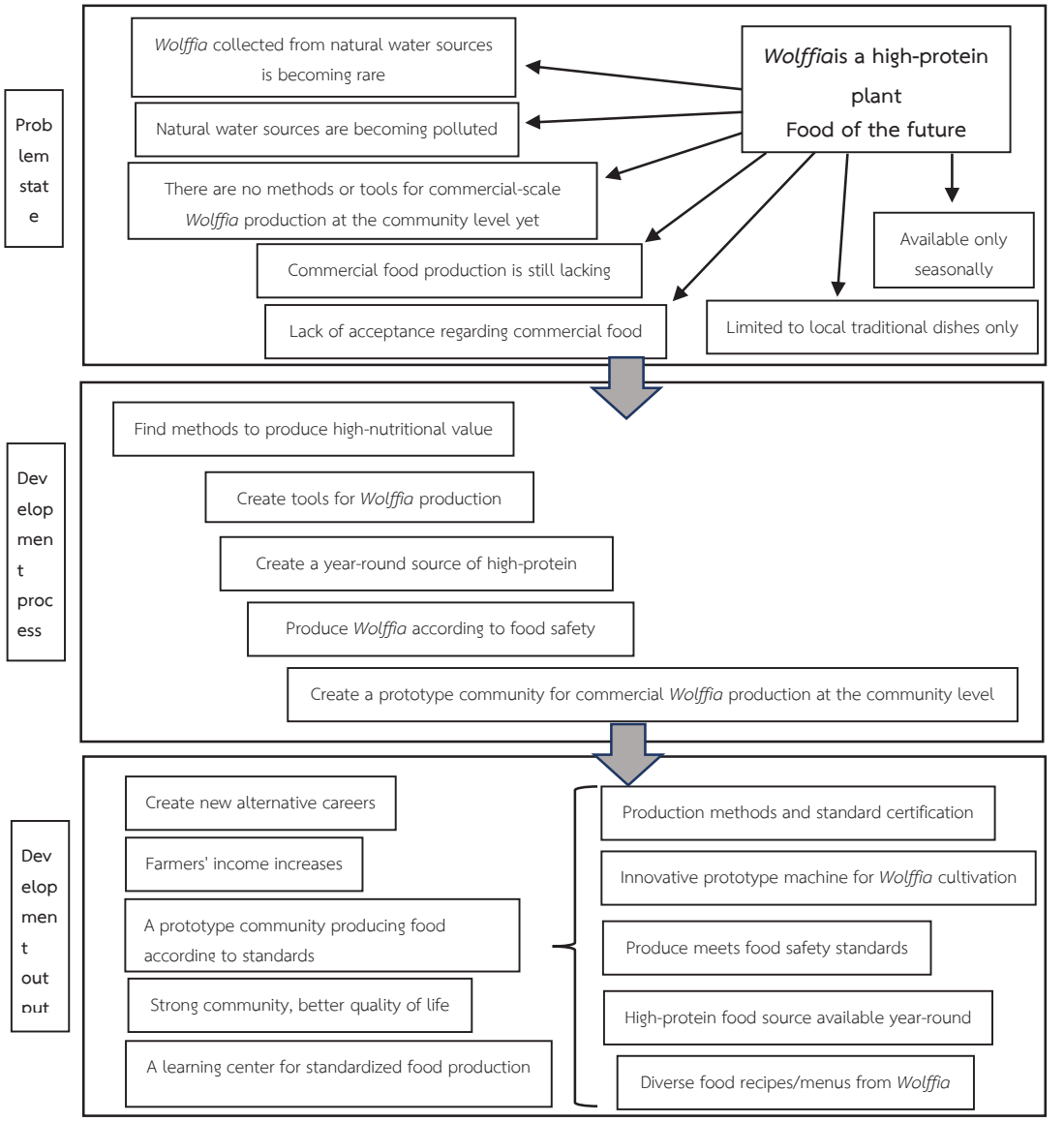

Figure 1. Framework and operational procedure

4. Research results

The research on innovation in closed-system Wolffia production and the development of high-protein commercial products at the community level in Maha Sarakham Province is divided into 3 phases according to the activity process, as follows:

4.1 Upstream activities

Technology for the production, cultivation, and utilization of Wolffia to increase its commercial value.

The technology for the production, cultivation, and utilization of Wolffia to increase its commercial value involves efficient and suitable cultivation methods and processes for the area. A simple cultivation model was developed to reduce production

costs by using materials available in the community, creating a prototype farm for Wolffia cultivation, along with knowledge about the suitable conditions for the cultivation process, enabling expansion to industrial-scale production.

Currently, there are 16 species of Wolffia in the genus Wolffia, including W. angusta, W. arrhiza, W. borealis, W. brasiliensis, W. Columbiana, W. denticulate, W. gladiata, W. globosa, W. hyaline, W. lingulata, W. microsvopica, W. netropica, W. oblonga, W. reanda, W. roanda, and W. welwitschii. However, only two species are found in Thailand: Wolffia arrhiza (L.) wimm and Wolffia globosa (L.) wimm, which are known by local names in Thailand such as Pham, Khai Pham, and Khai Haen. Research also shows Wolffia is found in European countries, Central and South Africa, Australia, Brazil, and Indonesia. The two species commonly cultivated for commercial purposes are Wolffia globosa (L.) wimm and Wolffia arrhiza (L.) wimm. The difference between the two species found in Thailand:

When viewed under a stereo microscope, W. arrhiza is larger, its upper surface is a relatively dark green, and the thallus is opaque. W. globosa is considered the smallest flowering plant, smaller than W. arrhiza, and is more cylindrical than W. arrhiza. Additionally, the thallus appears more translucent.

A B

Figure 2 Size characteristics of commercial Wolffia strains.
(A) Wolffia globosa (L.) Wimm.
(B) Wolffia arrhiza (L.) Wimm.

4.1.1 Technology and process for Wolffia cultivation under suitable conditions

Development of a Wolffia cultivation system in cement ponds, controlling water quality from the start until harvest. This compares traditional cultivation, where farmers typically use fermented animal manure water as nutrients, which may pose a risk of contamination by pathogenic microorganisms such as E. coli and coliforms, with the cultivation model in cement ponds using a researched and developed nutrient formula derived from plant protein to obtain essential amino acids and other nutrients

that plants can utilize most effectively. This avoids the use of chemical ingredients. This approach promotes Wolffia growth and new bud sprouting, allowing it to adapt to variable environments, and differs in terms of safety from contamination during the cultivation process, such as contamination by pathogenic microorganisms from natural water sources, and the use of a closed-system cultivation model, which can control external risk factors.

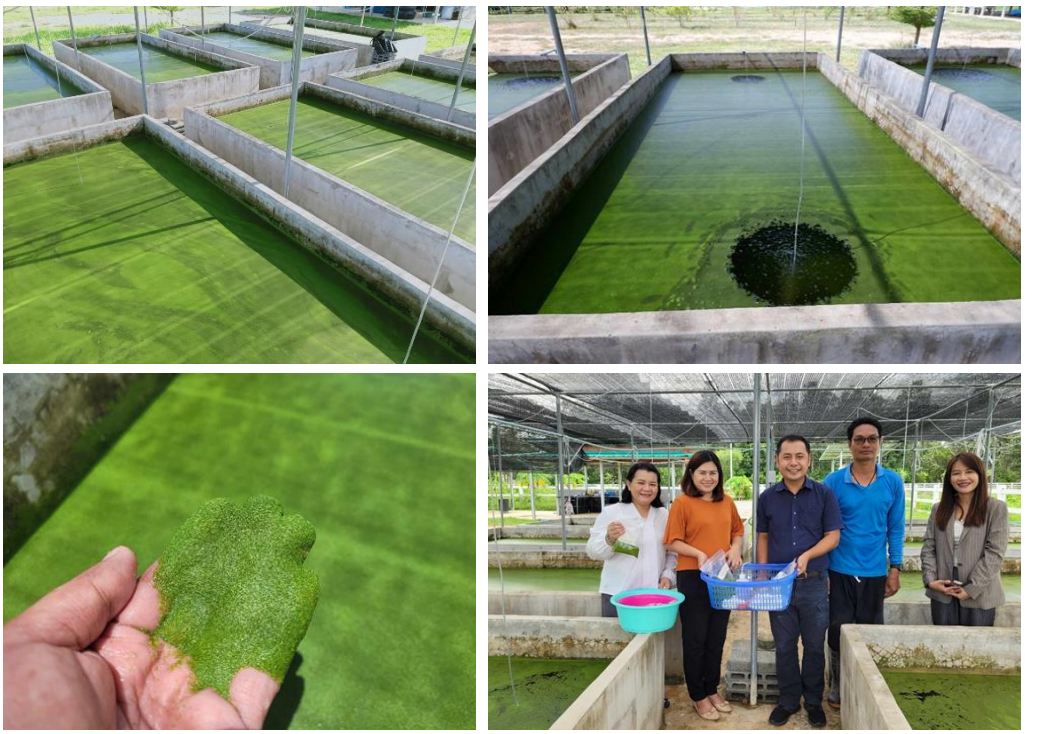

Figure 3 Cement-pond cultivation system for Wolffia with controlled water quality throughout the production process, from initiation to harvesting, compared with the traditional cultivation method.

Experiments were conducted to find the suitable model before transferring the technology to the community. Key strengths include establishing a farm management system model in preparation for requesting production standard certification and adherence to GAP (Good Agricultural Practices) standards, while also preparing for organic farming standards. The research involved developing a nutrient formula for Wolffia cultivation without chemical ingredients, establishing a production standard to build consumer confidence in safety, and preparing to develop the production model towards organic farming standards in the future.

4.1.2 Essential amino acid extract technology from plants used as nutrients for Wolffia cultivation

Development of plant growth stimulant technology from brown seaweed extract, which contains 17 types of essential amino acids for plant growth in the L-ami-

no acid group, such as tryptophan, which stimulates the production of auxin hormones (auxins) that regulate plant growth. These are absorbed through the plant's stomata and can be used immediately. This stimulant product was developed and enhanced to aid growth in combination with soybeans fermented with bromelain enzyme. This increases the quantity of humic acid, which can improve the cation exchange capacity (CEC) and increase the soil's buffering capacity against changes in pH levels compared to normal. The test results for the nutrient properties of the prototype product, obtained from the liquid concentrated solution production process, analyzed the quantity of primary nutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Humic acid content, and essential amino acid content for plants, as shown in Tables 1 and 2.

Table 1 Quantity of Primary Nutrients N, P, K, and Humic Acid.

Analysis Item	Test Result	Unit
pH	5.02	-
Phosphorus (Total P_2O_5)	1.12	% (wt/wt)
Total Nitrogen (Total N)	2.37	g/100 g
Potassium (Total K_2O)	1.46	% (wt/wt)
Humic acid	3.26	g/100 g

Table 2 Analysis of essential amino acids for plants in the Wolffia cultivation nutrient.

Test Item	Test Result	Unit
Amino Acid Profile		
Alanine	924.4	Mg/100 g
Arginnine	< 5.00	Mg/100 g
Aspartic acid	218.9	Mg/100 g
Cystine	94.81	Mg/100 g
Glutamic acid	712.6	Mg/100 g
Glycine	100.4	Mg/100 g
Histidine	488.7	Mg/100 g
Hydroxylysine	< 5.00	Mg/100 g
Hydroxyproline	< 5.00	Mg/100 g
Isoleucine	330.6	Mg/100 g
Leusine	738.8	Mg/100 g
Lysine	3101	Mg/100 g

Test Item	Test Result	Unit
Amino Acid Profile		
Methionine	37.79	Mg/100 g
Phenylalanine	829.4	Mg/100 g
Proline	147.1	Mg/100 g
Serine	78.66	Mg/100 g
Threonine	43.27	Mg/100 g
Tryptophan	68.70	Mg/100 g
Tyrosine	622.4	Mg/100 g
Valine	184.3	Mg/100 g

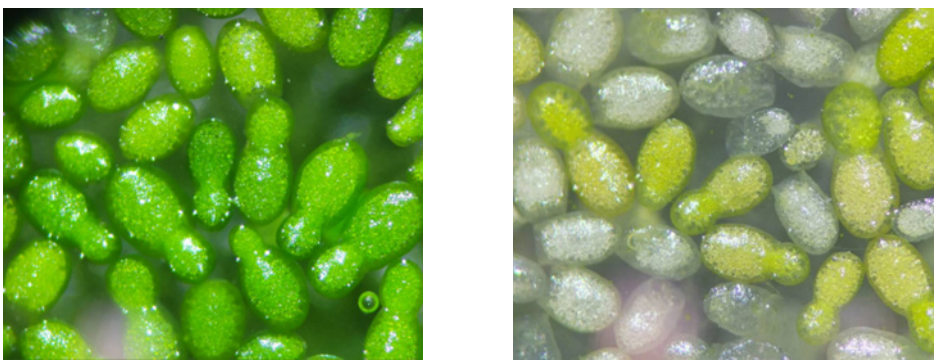

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Figure 4 Cement-pond cultivation of Wolffia with controlled water quality in the production process, comparing traditional cultivation using animal manure fermentate with nutrient solutions developed from the research.
(A) Wolffia cultivated in the research-developed nutrient solution.
(B) Wolffia cultivated in animal manure fermentate.

4.2 Midstream activities

Elevating Wolffia Production to Food Safety Standards.

Wolffia is a plant that can emerge and grow all year round under suitable water quality conditions. It grows well in soft water with total dissolved solids less than 200 milligrams per liter and hardness less than 100 milligrams per liter calcium carbonate. Wolffia cultivation ponds should have a low average light intensity with shade from trees or shading nets to provide indirect light. Crucially, the water must have a relatively low or slightly acidic pH value (5.0-6.0). It also requires complete and sufficient plant nutrients, with relatively high levels of ammonia nitrogen and orthophosphate, to ensure good growth and high yield.

4.2.1 Results of water sample quality analysis and nutritional value of Wolffia yield

1) Results of water quality analysis

The results of the analysis of water samples used for Wolffia cultivation at the initial stage before adding cow manure and seaweed fertilizer, the intermediate stage during cultivation with added cow manure and seaweed fertilizer, and the harvesting stage, were conducted to verify contamination of the cultivation water, cow manure fertilizer, and seaweed fertilizer.

Physical Analysis: The pH of the water before adding fertilizer was neutral. After adding cow manure and seaweed fertilizer, the pH was alkaline during both the cultivation and harvesting periods. Turbidity during the cultivation and harvesting periods was lower than at the initial stage before adding fertilizer, as were the total dissolved solids.

Chemical Analysis: Electrical conductivity of the water samples without fertilizer, and during cultivation and harvesting, was not significantly different. Total nitrogen and total phosphorus, indicating sufficient and complete plant nutrients for Wolffia cultivation, were found to increase after adding cow manure and seaweed fertilizer compared to water without fertilizer. Contamination by the three heavy metals (cadmium, lead, chromium) showed that the amount of cadmium exceeded the tap water standard (not exceeding 0.003 mg/L) in all water samples. The amount of lead was less than the standard (not exceeding 0.01 mg/L) in all samples. The amount of chromium was found in cow manure fertilizer, with a value exceeding the tap water standard (not exceeding 0.05 mg/L).

Biological Analysis: The quantity of total coliform bacteria exceeded the standard limit (must not be detected) in all water samples, including those without fertilizer and those with cow manure and seaweed fertilizer added. E. coli was not detected in any water sample, which meets the tap water standard (must not be detected). Details are shown in Table 3.

During cultivation, if the Wolffia pond receives too much sunlight, some green seaweed, especially Ulothrix aequalis, commonly found on aquatic plants in aquariums, will grow. This “attached seaweed” adheres to the Wolffia plants, preventing them from sprouting and reproducing, thus reducing the yield. This can be corrected by adjusting the pH of the culture water to 5.5-6.5 to control the growth of green seaweed. Additionally, larvae of freshwater midges or red worms may build nests in the culture pond. Red worms are food for small fish and are not harmful or carriers of disease, but the cultivator should change the water regularly to remove the red worms from the culture pond.

Table 3 Results of physical, chemical, and biological water sample quality analysis.

Water Quality Parameters	Tap Water Quality Standards	Cultivation Conditions							
		Initial Stage		During the Cultivation Stage			Harvesting Stage		
		Before Fertilizer	No Fertilizer (Control)	Natural	Cow Manure Fertilizer	seaweed fertilizer	Natural	Cow Manure Fertilizer	seaweed fertilizer
Physical Parameters (Units)									
pH	6.5-8.5	8.51	7.95	8.17	8.71	7.92	7.71	9.19	8.89
Temperature (°C)	N	28	29	27	28	27	29	29	28
Turbidity (NTU)	≤ 4	1.58	1.67	3.89	2.30	2.54	8.14	1.70	1.68
Total Dissolved Solids (mg/L)	≤ 600	701.10	703.88	697.37	696.87	697.23	694.47	694.40	694.07
Chemical Parameters (Units)									
Electrical Conductivity	-	1,402.50	1,327.50	1,394.67	1,393.67	1,394.33	1,389.00	1,389.00	1,388.00
(µS/cm)	≤ 50	NA	8.40	14	7	11.2	9.8	23.80	11.20
Total Nitrogen mg/L)	-	0.0246	2.5950	0.0491	0.0579	0.0292	1.5207	1.4132	0.3802
Total Phosphorus (mg/L)									
Cadmium (mg/L)	≤ 0.003	0.0140	NA	0.0568	0.0244	0.0235	0.0400	0.0321	0.0260
Lead (mg/L)	≤ 0.01	NA	NA	NA	NA	NA	NA	NA	NA
Chromium (mg/L)	≤ 0.05	0.0140	NA	NA	0.0230	NA	0.0276	NA	NA
Biological Parameters (Units)	Not	6	9.2	6.2	>2,400	1,100	16	>2,400	
Total coliform	detected								1,100
(MPN/100 ml)	Not	NA	NA	NA	NA	NA	NA	NA	
E. coli (MPN/100 ml)	detected								NA

Note: N indicates natural condition.

2) Results of nutritional value analysis of Wolffia yield

The results of the nutritional analysis of the Wolffia yield (protein, fat, crude fiber) from samples collected during the cultivation period and at the harvesting stage after the cultivation concluded. It was found that, per 100 grams of Wolffia dry weight, the average percentage of protein, fat, and crude fiber in Wolffia at the harvesting stage cultivated in ponds with added seaweed fertilizer was higher than in ponds with added cow manure fertilizer. It can be seen that Wolffia yield cultivated for a single harvest at the harvesting stage has a higher amount of protein, fat, ash, and crude fiber than harvesting over short periods during cultivation. Details are shown in Table 4.

Table 4 Results of nutritional value analysis of Wolffia yield.

Parameter (Wolffia 100 g)	Cultivation condition					
	During cultivation			Harvesting Period		
	Natural	Cow Manure Fertilizer	seaweed fertilizer	Natural	Cow Manure Fertilizer	seaweed fertilizer
Protein (%)	4.40	14.40	13.90	8.80	15.20	17.14
Fat (%)	2.20	2.70	2.90	3.30	3.60	3.60
Fiber (%)	2.07	2.17	2.40	3.33	3.49	4.12

4.3 Downstream activities

Development of Prototype Products and Wolffia Processing to Increase Commercial Value.

For the development of prototype products and Wolffia processing to increase the commercial value of agricultural produce and generate sustainable income for the community, the researchers developed products by incorporating Wolffia into food. Three products were developed: Wolffia ice cream, Wolffia spaghetti noodles, and Wolffia gummy jelly.

4.3.1 Wolffia ice cream

Wolffia ice cream is made as homemade ice cream. It uses small machinery, is easy to make, and has a unique flavor. Most ingredients are entirely natural, fresh, and readily available in the market. Therefore, in this research, the researchers experimented with making green tea ice cream, which includes the following ingredients and production steps.

1) Materials and equipment

1.1) Ice Cream Scoop 1.2) Digital Scale 1.3) Plastic Ice Cream Tray 1.4) Stainless Steel Mixing Bowl 1.5) Hand Mixer

2) Ice cream ingredients

2.1) Condensed Milk: 100 ml 2.2) Green Tea Powder: 15 g 2.3) Whipping Cream Powder (Unsweetened): 200 g 2.4) Pasteurized Fresh Milk (Unsweetened): 400 ml 2.5) Wolffia (Dried Roasted): 15 g

3) Preparation Steps

3.1) Measure 200 g of whipping cream powder and mix with 400 ml of very cold fresh milk194. Stir until combined, then use the hand mixer at the lowest speed until the whipping cream forms stiff peaks.

3.2) Weigh 15 g of green tea powder and 15 g of Wolffia (cooked by dry roasting). Mix them into 100 ml of condensed milk and stir until combined. Then pour the mixture into the whipped cream that has formed stiff peaks and use the hand mixer to blend until homogeneous.

3.3) Pour into the prepared container, close the lid, and freeze for 5-6 hours until the ice cream hardens.

Figure 5 Characteristics of Wolffia prepared by drying before its use as an ingredient in ice cream to enhance nutritional value.

4.3.2 Wolffia spaghetti noodles

Making fresh spaghetti noodles from Wolffia is a new concept that blends traditional Italian pasta culture with local Thai ingredients. Wolffia has high nutritional value, especially protein and antioxidants, and is an easily obtainable local food source. Therefore, the researchers conceived of incorporating Wolffia into the pasta-making process. This not only increases the nutritional value of the pasta but also creates a unique identity for food inspired by Italian culture. Using Wolffia in fresh spaghetti noodles not only adds color and a unique flavor but also supports the use of local ingredients and seamlessly connects the two food cultures. Details are as follows:

1) Materials and equipment

1.1) Mixing Bowl: For flour and egg mixing 1.2) Fork or Whisk: For beating eggs and mixing flour 1.3) Rolling Pin: For rolling the dough to the desired thinness 1.4) Pasta Machine: For rolling and cutting the pasta noodles evenly 1.5) Plastic Wrap: For wrapping the dough while resting 1.6) Cheesecloth or Damp Cloth: For covering the dough while resting to prevent it from drying out 1.7) Large Cooking Pot: For boiling the pasta noodles 1.8) Strainer or Colander: For draining water after boiling the noodles

2) Spaghetti Noodle Ingredients

2.1) All-Purpose Wheat Flour: 250 g 2.2) Chicken Eggs: 2 eggs 2.3) Salt: 2 g 2.4) Olive Oil: 10 g 2.5) Wolffia (Dried Roasted): 10 g

3) Preparation Steps

3.1) Prepare the flour by sifting it onto a clean surface (or placing it in a large mixing bowl) and creating a well in the center like a volcano.

3.2) Crack the eggs into the well, add salt, Wolffia, and olive oil.

3.3) Knead the dough by gently beating the eggs with a fork into the flour, then gradually incorporating the flour from the outside to the center. Knead until all ingredients are combined. If the dough is too dry, add water a little at a time.

3.4) Continue kneading until the dough is smooth. When the dough starts to come together, continue kneading by hand on a lightly floured surface for about 8-10 minutes until the dough is soft, flexible, and smooth.

3.5) Rest the dough by wrapping it in plastic wrap or a damp cloth and letting it rest for about 30 minutes to allow the gluten to relax, making the dough more flexible.

3.6) Once rested, roll out the dough using a rolling pin or a pasta machine, gradually rolling the dough to the desired thinness.

3.7) When the dough is thin enough, cut it into spaghetti noodles using the cutting attachment on the pasta machine.

3.8) Boil salted water and cook the fresh noodles for about 2-3 minutes, as fresh noodles cook faster than store-bought dry pasta.

5. Conclusion

Technology for the production and cultivation of Wolffia focuses on developing efficient cultivation methods to reduce costs and increase commercial value, utilizing community materials to build a prototype farm. The two main species of Wolffia in Thailand are Wolffia arrhiza and Wolffia globosa, which have different physical characteristics and growth patterns. The cultivation method was developed in cement ponds, controlling water quality and using plant-based nutrients instead of fermented animal manure, reducing the risk of contamination from pathogenic microorganisms such as E. coli and coliforms. The developed nutrient formula, derived from plant protein and amino acids, helps accelerate Wolffia growth. Stimulants from brown seaweed extract and the use of enzymes enhance the efficiency of humic acid and nutrient quantity. This cultivation system development also aims for GAP and organic farming standards to build consumer confidence and prepare for industrial-level production.

The results of the water sample quality analysis for Wolffia cultivation at the initial stage before adding fertilizer, the intermediate stage during cultivation with added cow manure and seaweed fertilizer, and the harvesting stage, were conducted to verify contamination of the cultivation water. The physical and chemical water quality analysis results met the tap water standards, except for the quantities of heavy metals cadmium and chromium, which exceeded the tap water standards, possibly due to contamination from cow manure fertilizer and seaweed fertilizer. Biologically, the quantity of total

coliform bacteria exceeded the standard limit in all cultivation water samples. Therefore, Wolffia should be washed thoroughly with clean water multiple times or cooked before consumption. The nutritional value analysis of the Wolffia yield showed that protein, fat, and crude fiber during the harvesting stage in ponds with added seaweed fertilizer were higher than in ponds with added cow manure fertilizer. Wolffia yield cultivated for a single harvest at the harvesting stage has a higher amount of protein, fat, and crude fiber than harvesting over short periods during cultivation.

The development of prototype products and Wolffia processing to increase commercial value was developed to extend the value of agricultural produce and create sustainable income for the community. This involves incorporating Wolffia into food, such as Wolffia ice cream and Wolffia spaghetti noodles.

Wolffia ice cream: This is homemade ice cream production, blending dried roasted Wolffia into green tea ice cream. The main ingredients are natural, such as condensed milk, pasteurized fresh milk, and whipping cream. The addition of Wolffia increases nutritional value, such as protein and antioxidants.

Wolffia spaghetti noodles: This involves incorporating dried roasted Wolffia into the fresh pasta-making process, mixing it with wheat flour and chicken eggs. This gives the pasta a unique color and flavor, and also increases its nutritional value. It promotes the use of local ingredients and connects them seamlessly with Italian pasta culture.
Both products focus on using natural ingredients and processing to add value to Wolffia, creating food innovation that promotes the use of local resources.

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