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Article

Development of Potential Indicators of Aquaponics Industry

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Abstract: Aquaponics is a sustainable method of farming fish and vegetables, so it is highly valued by individuals, entrepreneurs, educators, and governments. It is a special aquacultural method that creates economic and ecological benefits. Considering that the development of the aquaponics industry is leading the ecological fishery industry in the future, a set of indicators to evaluate the potential of the aquaponics industry is necessary to be developed. Therefore, a literature review and the Delphi method were used to establish a set of indicators for the investigation of the development of the aquaponics industry. As a result, the key implementation strategies were proposed from five aspects: environmental conditions, resource conditions, industrial conditions, technical conditions, and policy conditions of aquaponics. In the central trend analysis, 48 potential indicators of the aquaponics industry were defined. Important indicators were found in the environmental and resource conditions, followed by industrial and technological conditions, and policy conditions in the order of the number of indicators. The most important indicators were "water quality control: complete technical knowledge of water temperature control or operation of dissolved oxygen nutrients" and "water pollution control: have generated water pollution control or operation technical knowledge". For future strategies, we suggested the following implementation strategies: (1) taking the aquaponics industry as the important object of rural revitalization policies, (2) taking various indicators as the basis of policy implementation, and (3) establishing the promotion group of aquaponics.

Keywords: Aquaponics, potential indicators, Delphi method

1. Introduction

Aquaponics technology is called the Integrated Agri-aquaculture System (IAAS) which includes various forms and types of aquaculture practice combined with plant-based agricultural production [1]. The principle of IAAS is to develop and achieve economically viable and environmentally sustainable primary production through the sharing of resources such as water and nutrients between aquaculture and crop production. With the improvement of the economy, people's demand for health and nutrition gradually grows. Consumption patterns have also shifted from quantity to quality. Aquatic products are chosen by more consumers because of their high nutritional value and special health functions. This has gradually increased the proportion of aquatic products in the dietary structure [2,3]. Producers blindly tend to pursue economic benefits and increase production by expanding the farming area, increasing the density and feeding amount. This has resulted in the discharge of a large amount of wastewater from fish farming directly into the environment without effective treatment. Therefore, environmental pollution and the decline in the quality of aquatic products are becoming more [4−6].

Under sustainable development, high efficiency, high yield, high quality, green, and pollution-free are not only pursued by agricultural producers but also by the majority of consumers. Thus, an intensive and ecological aquaponics system combining fish farming and vegetable cultivation comes into being. In aquaponics, nitrate in the system is removed efficiently to ensure the stability of water quality in the system, producing green and healthy vegetables as by-products and reducing greenhouse gas emissions. Therefore, the goal of the development of aquaculture has been changed from extensive management, single production increase through structural adjustment, improving quality, and improving efficiency to the green fishery, circular fishery, and ecological fishery development.

The aquaponics system is a new technology that combines traditional fish farming with planting technology and integrates multiple disciplines [7,8]. Its mechanism is to transport the animal excreta in the breeding tank through the pipeline to the planting tank and transport the water back to the breeding tank after microbial transformation, plant root absorption, and filtration. In the same environment, the dynamic circulation system is used to skillfully combine microorganisms, animals, and plants to form a sustainable production [9]. This balanced system allows long-term fish farming without changing water, plant planting without fertilization, intensive production, and water resource saving [10]. The aquaponics system is not a simple single ecosystem. The symbiotic balance of fish, microorganisms, and vegetables maintains the stability of the system. Therefore, the selection and matching ratio of fish and vegetable species require in-depth research and production application. Relevant breeding and planting techniques also need to be chosen carefully. In particular, relevant professional knowledge is required to ensure the normal growth and nutritional requirements of vegetables and fish and to maximize the benefits of farming. With the demand for management using artificial intelligence in modern agricultural production, it is required to establish a mathematical model of fish and vegetable symbiosis production and develop stable production intelligent management equipment to reduce labor costs and improve farming efficiency. With further research of technology, the popularization of facilities and equipment, and the help of artificial intelligence, aquaponics will play a more important role in the future of agriculture.

2. Literature Review

In developing indicators of the aquaponics industry, the definition and theory of aquaponics are needed. The indicators related to aquaponics may be numerous and complex. Therefore, to define the potential indicators of aquaponics, the demand of fishers, the connotation of aquaponics, and the development status need to be considered.

2.1 Related Theories of Aquaponics

The aquaponics system is a new model of circular aquaculture based on the integration of multiple disciplines. It is a compound production system with aquaculture and soilless cultivation to create mutual benefits based on the concept of the natural ecological cycle. It is also the main operating principle of the aquaponics system, an ecological agricultural technology with green, healthy, and sustainable characteristics [11−13]. Fish's digestion in aquaculture produces excrement, residual feed, and ammonia nitrogen. Aerobic microorganisms transform ammonia nitrogen into nitrite, which is toxic to fish, and, then, nitrite into nitrate which is absorbed and utilized by plants. Nitrate in water is assimilated and absorbed by plants through nitrogen fixation, forming a nitrogen cycle in the aquaponics system, thereby generating a nutrient cycle [14]. Being different from the operation of two independent systems, the aquaponics system has the characteristics of the two systems operating at the same time. In a limited space, the aquaponics system reduces the input of nutrients and the output of wastes to the greatest extent. Compared with a single breeding industry or aquaculture industry, the same input of nutrients and the same space in the system can be achieved for the three-dimensional production of efficient and economic products at the same time. In the aquaponics system, the wastewater from aquaculture provides nutrients for vegetable growth and is purified through the absorption and assimilation of plant roots [15].

2.2 Current Situation and Prospect of Aquaponics Industry

Based on the research of "Ecological Ark" in the United States, aquaponics systems have been successively developed and continuously developed. In 1980, James Wachs in the United States successfully developed the UVI model of aquaponics for the first time [16], which is suitable for large-scale outdoor production. At the same time, Doug and his students also successfully developed the NCSU model of greenhouse solid matrix cultivation [17], which is the prototype of current cultivation and cultivation symbiosis. Studies on aquaponics have entered a mature stage, and three-dimensional planting based on the principle of ecology with various plants is developed focusing on productive vegetables such as traditional Chinese medicine, flowers, and plants.

The history of aquaponics in China can be traced back to the rice fishing technology 1200 years ago, and this traditional farming technology is still used widely in southern China [18]. With the development of modern science and technology, the need of the modern society has not been met with traditional technology. Thus, modern ichthyosymbiosis technology has been introduced. Since the intensive research of aquaponics systems had been started in 1988, the technical appraisal of aquaponics systems was recognized by the Chinese Fisheries Association in 1991, and the related research of the aquaponics system has been studied by Ding and Zhang [19−21]. With social development, the modern aquaponics symbiosis system has been improved to provide high integration and economic benefits. After more than 30 years of development, modern aquaculture technology has been relatively mature [22]. Its development shows a diversified planting model, which has been widely applied in various farming industries [23,24].

2.3 Advantages of Aquaponics

Saving water

Aquaponics saves a significant amount of water. By comparing the aquaponics system with the pond aquaculture system, the daily water loss rate of the aquaponics system was similar to that of the pond aquaculture system by about 1% [25]. Love et al. also found that a small deep-water aquaponics experimental system showed a daily water loss rate of about 1% [26].

High nutrient utilization

Aquaponics has an important advantage in the efficient distribution and utilization of nutrients [27−29]. In recirculating aquaculture, fish absorb and utilize only 25% of the feed, that is, 75% of the nutrients are wasted. In aquaponics, the wasted nutrients are used in recirculating aquaculture systems (RAS) for plant production, producing two food products from one input source.

Eco-friendly

As ecological, aquaponics uses soilless cultivation techniques. Aquaponics facilities are more freely located and built in a more manageable location without considering soil fertility, which gives them advantages over traditional soil-based agriculture. At the same time, aquaponics adopts natural ecosystems, creating complex aquatic ecosystems that facilitate the healthy growth of fish and plants. Traditional aquaculture methods directly discharge nutrient-rich wastewater into the surrounding environment, which may lead to the eutrophication of the surrounding water. Hydroponics methods also have the same problem. As an aquaponics system combines waste generation (aquaculture unit) with nutrient absorption (planting unit), it significantly reduces or even eliminates the impact of aquaculture wastewater discharge on the environment.

2.4 Key Success Factors

To evaluate the degree of completion of specific goals, there must be indicators. Therefore, the connotation of key factor indicators is proposed for discussion in this section.

Key Success Factors

The early concept of Critical Success Factors (CSF) was proposed by Daniel in 1961. He suggested that in most industries, there are usually three to six factors that determine success, which must be done for success. Hofer and Schendel (1979) proposed that "key success factors" refer to variables on which managers' decisions fundamentally affect an enterprise's competitive position in the industry. Rockart introduced key success factors for information systems, which are used by senior managers to analyze operational information. The information needed for senior managers to make decisions is based on limited but important factors. Therefore, the key success factors need to influence the success of industry development or transformation. It refers to a limited number of influential factors, generally three to six. If managers cannot control all the factors, they need to focus on a limited number of key factors to determine the transformation method and path. The Organization for Economic Cooperation and Development (OECD) (1994), pointed out that the index is derived from parameters or values to provide information and describe the phenomenon, the state of the environment, and the region [30]. Hong (1995) believed that an index is a measure that gives data judgment to a certain situation to show the level of the situation [31]. To sum up, the key factor is to evaluate and judge the value of the object or subject by some relevant standards or parameters.

Function of Key Factor Indicator

The developed indicators describe the status quo and reflect the gap between the status quo and the ideal standard as well as the reference for improving strategies. Therefore, the function of the key factor is the understanding of the status quo and niche to provide information for the evaluation of the overall development potential.

Selection Principles of Factor Indicators

Dunn (1981) [32] proposed the selection principles of indicators as relevance, importance, validity, reliability, objectivity, timeliness, and usefulness. Chen (2002) mentioned that the selection of indicators must have representativeness and theoretical basis in addition to stability, reliability, and credibility. The establishment of indicators must be concise and easy to understand, and the data must be available in a real environment [33]. Lin (2004) believed that the key factor indicators must reflect the core and concept of the problem and proposed the following seven principles: effectiveness, availability, stability, understandability, relevance, importance, and practicality [34]. Key factor indicators are parameters that reflect reality, including quantitative data and qualitative meaning. The construction or use of indicators must comply with the above principles and exclude all possible interference factors.In selecting indicators, experts in professional fields must be invited, and their opinions need to be summarized to ensure the accuracy and rationality of the indicators.

3. Materials and Methods

3.1 Research Design and Process

We adopt the Delphi method which is divided into three stages. First, the connotation and essence of aquaponics are discussed. Through data collection and analysis, the index of the aquaponics industry is defined. In the second stage, a formal investigation is conducted using the Delphi method. Then, according to the results, the connotation of each index is analyzed, and a set of evaluation index systems is formulated. Finally, according to the indicators, the viewpoints of different objects are compared, the focus of each indicator is analyzed, and the implementation strategy for the development of the aquaponics industry is proposed. The construction and research flow of the five main dimension indicators is shown in Fig. 1.

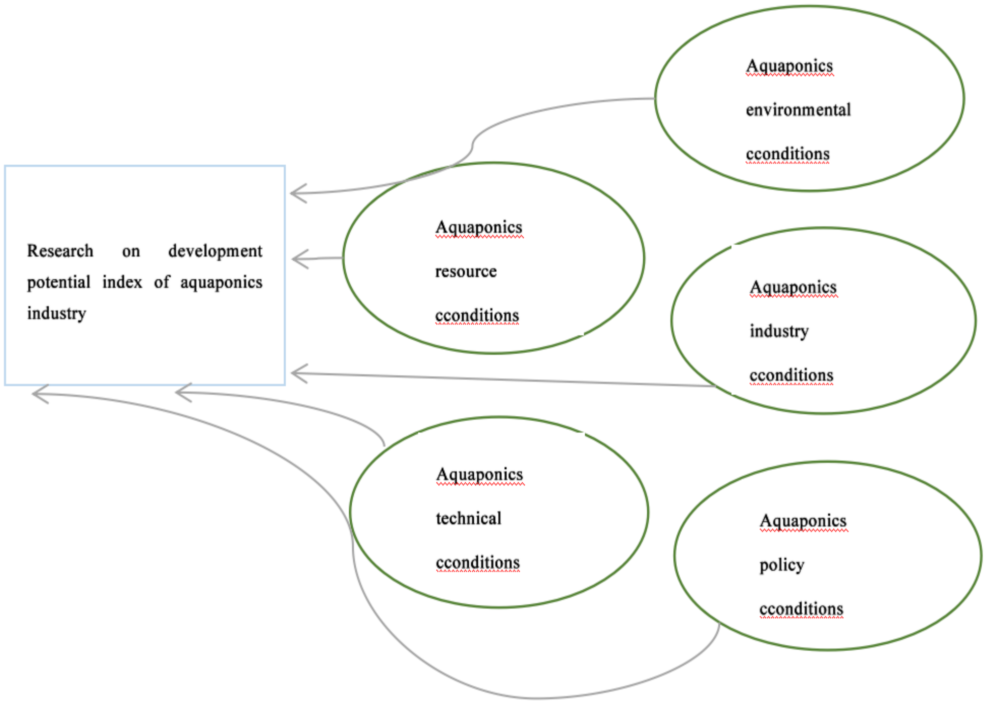

Fig. 1. Five main dimension indicators of the research.

3.2 Delphi Method

In the past, many indicators were formulated using expert in-depth interviews, the Delphi method, and the analytic hierarchy process. In the Delphi method, the expertise of individual respondents is used in conjunction with the research topic, the sponsor of the research, and the objectives. Since this study is focused on the identification and consensus of experts on indicators, the simplest form can be a round table meeting. A compromised virtual consensus emerges from the group's pressure and psychological factors.

The Delphi method was first developed by Helm and Dahlke in the 1940s and further developed by Gordon and Rand. In 1946, RAND Corporation used this method for qualitative prediction for the first time. To avoid blind obedience or submission to authority in the collective discussion, this method was widely and rapidly applied in the military, technology, medical, marketing, and other industries. The Delphi method is a development of the expert meeting forecasting method, in which the opinions of experts are solicited anonymously through several rounds of correspondence until the opinions of expert group members converge to achieve the purpose of forecasting. The Delphi method is conducted by group thinking of relevant government departments, scholars, and experts, and gradually research topics are converged into the results of group decision-making through questionnaire surveys and statistical analysis..

The result is provided for decision-makers as a reference for policy formulation. The main principles are as follows.

Anonymous Responses

Anonymous responses ensure that experts "speak freely" in consultation and do not reserve or modify opinions purposefully. Anonymity ensures the adequacy and reliability of expert opinions.

Repetition and Control Feedback (Iteration and Control feedback)

In the Delphi method, anonymity is guaranteed. Mutual contact between experts is avoided so that expert opinions tend to be scattered. As it is not easy to conclude, to make the invited experts understand the summary of each round of consultation and other experts, the organizer must sort out, analyze, and synthesize the results of each round of consultation and feedback to each invited expert in the next round of consultation. Then, the experts can further express their opinions according to the new questionnaire.

Group Response

The Delphi method is an effective way to gain and measure group consensus. The answers of experts must be statistically processed in the method so that the results obtained have statistical significance. The result often is expressed as a probability, which reflects the degree of concentration and dispersion of expert opinions.

The Delphi method requires experts and scholars as survey objects, so selecting appropriate experts and scholars is one of the important factors affecting the accuracy of survey results. There is no standard for the selection of experts, but the literature research shows that every expert must meet the following four conditions.

1) The professional requirements: The professional direction of an expert must be one or several specific fields, and the definition of an expert is mainly based on professional knowledge (including the professional title, years of service, the number of representative works, and other quantitative indicators)
2) Energy permit: Experts agree to invest time and energy in the research. Due to multiple rounds of research, experts may get lost in the process. To avoid withdrawal, the selected experts must be the most suitable candidates by explaining the importance of the project and other background information and be motivated.
3) Freedom of speech: Experts can "speak freely" without worrying about the possible consequences of their judgment. The main purpose of the Delphi method is to collect the opinions of individual experts, rather than the opinions of their affiliated organizations. Therefore, experts must freely express their opinions, rather than judge on behalf of an organization.
4) Open feedback: Experts can actively give feedback on the results of each round, especially when the opinions of individual experts and the collective opinions of experts are different. Experts must explain their own opinions (Ni Zongzan, 1995; Chocholiketal., 1999).

3.2 Questionnaire Design and Investigation Process

3.2.1 Evaluation indicators

A preliminary questionnaire was prepared for the research on the potential indicators of the aquaponics industry. The related measures are shown in Table 1. There was an index structure at three levels and five categories, including environment, resources, industries, technology, and policy. In the indicator architecture, the second level is for the subcategories and the third level is for the indicators. A total of 52 indicators are included in this study. To avoid face-to-face contact, repeated questionnaires were used to conduct private consultations.

Table 1. Overview of the categories.

Main category	Subcategory	Indicators	Indicators description
1. Environmental conditions of aquaponics	Natural environment	1-1 Climatic conditions	Suitable climate of light, rainfall, etc
		1-2 Environmental load bearing	Whether the environment has a sufficient load capacity
		1-3 Negative impact	Negative effects of the environment

	Environment of industry	1-4 Economic environment	The willingness of local businesses or fishermen to invest capital
		1-5 Social environment	The willingness of local businesses or fishermen to invest
		1-6 Laws and regulations	Whether there are relevant laws and regulations for aquaponics
2. Aquaponics resource conditions	Water resources	2-1 Source of water resources	There are available water resources including river reservoirs
		2-2 Quality of water resources	With excellent water quality
	Land resources	2-3 Buildable private field	Available fish pond rice field open house factory
		2-4 Buildable public spaces	Rivers, highlands, lakes and reservoirs available or rented
		2-5 Industrial park	The industrial park promoted by the government
	Aquatic living resources	2-6 Economic fish	Having available economic fish species
		2-7 Aquatic economic plant	Have available aquatic economic plant species
		2-8 plankton	There are available plankton species
3. Conditions of aquaponics industry	Money	3-1 Enterprise or fisherman's funds	Capital invested by enterprises or fishermen themselves
		3-2 Financing by enterprises or fishermen	Bank loans available to enterprises or fishermen
		3-3 Industrial development fund	Aquaponics industry development fund was provided to support the development of new varieties and technologies
	Labor force	3-4 The labor market	There is an abundance of Labour in the area
		3-5 Introduction of talent	Supplement enterprises or fishermen lack of talent
		3-6 Technical training	Improve the scientific quality of enterprises or fishermen
	Technology	3-7 Technology of production	The region has complete production technology and knowledge
		3-8 Improve science and technology services	Technology services available
		3-9 Industry-university-research cooperation	Research institutes that can coordinate
	Operating market	3-10 Mechanism of operation	Enterprises or fishermen have effective operating mechanisms
		3-11 Business model	Enterprises or fishermen have a unique business model
		3-12 Supply chain	The region has a complete supply chain
4. Technical conditions for aquaponics	The water quality	4-1 Water quality control	Complete technology and knowledge of water temperature dissolved oxygen nutrient control or operation
		4-2 Water pollution control	Have the generated water pollution control or operation technology and knowledge
	Farmed animals	4-3 Breed of animal	Have the right breed of animal
		4-4 Density of breeding	With a suitable proportion of breeding density
		4-5 Pathological treatment of animals	Have the ability and knowledge to treat and restore pathological management
		4-6 Animal environmental treatment	Ability and knowledge to resist environmental change
	Cultivated plants	4-7 Varieties of plants	With suitable plant varieties
		4-8 Density of planting	With a suitable proportion of planting density
		4-9 Pathological treatment of plants	Have the ability and knowledge to treat and restore pathological management
		4-10 Plant environmental treatment	Ability and knowledge to resist environmental change
	Microorganism	4-11 Varieties of microorganisms	Have the right microbial variety
		4-12 Symbiosis of bacteria and algae	Ability and knowledge to develop bacterial and algal symbiosis models
5. Aquaponics policy conditions	Supporting policies	5-1 money	Whether there is money available for grants, awards or coaching
		5-2 Demonstration base and industrial park	Whether there are demonstration bases and industrial parks
		5-3 Product logistics system	Whether it has technical support for cold chain preservation of agricultural products
		5-4 Finance, taxation and finance	Whether it has fiscal, tax and financial support policies
	Management policy	5-5 A specialized organization	Whether there is a specialized organization to carry out supervision and management activities
		5-6 Management Work	Carry out planning, supervision, control and management activities
		5-7 Laws and regulations	Whether there are laws and regulations for the development of aquaponics

	Sustainable development Policy	5-8 Development policy	Whether there is an aquaponics sustainable development policy
		5-9 Concept of sustainable development	Economic construction should be carried out under the conditions of protecting the environment and sustainable use of resources
	Recreational fisheries policy	5-10 Develop aquaponics recreational fisheries	Whether it has an aquaponics recreational fisheries policy
		5-11 Recreational fishery development concept	In the tertiary industry concept to develop aquaponics recreational fisheries
	Conditions of innovation	5-12 Food safety	We will adjust and optimize the structure of the food industry and establish a stable mechanism for ensuring input in food production
		5-13 Water saving	Take the scientific research of water saving technology as the strategic goal of innovation
		5-14 Greening	Take greening as the goal of innovation strategy

3.6.2 Investigation process

Questionnaires were sent by mail or fax. Two rounds of expert and academic consultations and tests were conducted. For qualified experts and scholars, 12 solicitations were sent out in the first round, and all questionnaires were returned. There were three experts from Taiwan and 9 from China and all experts were from academics. In the second round, 14 letters were sent out for comment, all of which were returned. There were three experts from Taiwan and eleven from China, all experts were from academics. The operation process is as follows (Table 2).

1) Determining the purpose of the research: This study was carried out to build an objective and fair evaluation index system for the future development
2) Determining the consulting objects: Experts and scholars in aquaponics management and decision-making positions in government departments were selected as the consulting objects and conducted a questionnaire survey.
3) Desiging questionnaire
4) Collecting statistical data of the first- and second-round questionnaires
5) Compiling and analyzing the questionnaire survey results

Table 2. Implementation process of questionnaire

Order and time	Work content
Pre-work September 1-9, 2022	1. Experts are invited to evaluate the first draft of the questionnaire design. 2. Revise and complete the first round of the Delphi questionnaire.
Delphi questionnaire Round 1 September 12-30, 2022	1. Delphi experts receive a research explanatory letter and the first round of questionnaires 2. Delphi experts fill in each item and send it back
Delphi questionnaire Round 2 October 10-28, 2022	1. Delphi experts received the second round of questionnaires, together with the records and analysis results of the first questionnaire. 2. Delphi experts fill in each item and send it back.
Data processing	Results Pooling and Reliability Test of Questionnaire Results

3.6.3 Questionnaire Design

For the validity test of the questionnaire, expert validity (also called content validity) was used. The first draft of the second Delphi questionnaire was formulated according to the evaluation index content of the Delphi questionnaire. During the process, Taiwanese experts (scholars) conducted interviews and evaluations on the correctness and necessity of the questionnaire content and revised and completed the second-round questionnaire (Table 3).

Table 3. Correction result of the second-round questionnaire.

Facet	Correction item	Correction result
Environmental conditions		It is suggested to increase the effect of pests on aquaponics It is suggested to increase the degree of close integration with actual cases

The first-round questionnaire was designed in a semi-open format with the concept of "environmental conditions", "resource conditions", "industrial conditions", "technical conditions" and "policy conditions". There were 57 indicators in five dimensions. In both rounds of discussions, experts and academics were invited to focus on each indicator (measured on a Likert 5-point scale, very important 5, important 4, average 3, unimportant 2, and very unimportant 1). and further clarification of the other comments. After collecting questionnaires, statistical analysis and their comments were summarized.

The second round was a closed questionnaire. The content of the questionnaire was listed as the survey results of the first round, and the opinions were supplemented by experts. Then, the questionnaire survey was repeated to converge their opinions. Therefore, in this round, we asked the experts to refer to the first round. According to the results of the questionnaire, comments and opinions were reflected in the questionnaire. The first part of the questionnaire contained the supplementary explanation for the compilation of expert opinions after the previous round of questionnaires was collected, and the second part was to check the indicators. The third part included open-ended comments and opinions from the experts.

Table 4. Questionnaire survey schedule

	The first round	The second round
Sending a questionnaire	On September 12th, 2022	On October 10th, 2022
Questionnaire recovery	On September 30th, 2022	On October 28th, 2022

In the first round of this study, 12 questionnaires were issued, and 12 were recovered, with a recovery rate of 100%, and all the recovered questionnaires were valid. In the second round, 14 questionnaires were issued, and 14 were recovered, with a recovery rate of 100%. In the reliability analysis, the overall reliability of the first round was. While the overall reliability of the second round is. All of these have high reliability, indicating that the data obtained from the returned questionnaires in this study are quite high.

4. Results

18 reviews were identified during the testing period. Fourteen reviews satisfied the inclusion criteria. The number of indicators reviewed was initially 57, and 2 indicators were added later based on expert opinion after the first round. The analysis was conducted after two rounds of the questionnaire survey. The results of the two rounds of surveys and feedback are shown in Table 5.

The Delphi method's main purpose is to converge the opinions of experts and reach a consensus. At present, there is no conclusion on what is the best convergence condition in the Delphi method. The most commonly used statistical data for opinion convergence are the median, mean, and standard deviation. When the standard deviation (SD) of most indicators of the first and second rounds of the questionnaire survey is small and the SD of the second round is less than that of the first round, the result is considered to be converged. Then, the next round of the questionnaire survey is not conducted. The standard deviation and the consistency test result obtained from the second-round questionnaire are presented in Table 5. According to the previous research on evaluation indicators of the "concentrated potential analysis", the indicators with an agreement ratio of over 67% were accepted and listed. In other words, the indicators with a ratio less than the standard were deleted and marked as 'deleted'. Finally, 11 indicators were deleted. The dimension that experts paid the most attention to was "Aquaponics environmental conditions". The important aspects of aquaponics were environmental and resource conditions, followed by industrial conditions and technical conditions, and finally policy conditions.

Table 5. Standard deviation and consistency test result of the questionnaire survey

Question	The first round			The second round			Remarks
	Average	Mode	Standard deviation	Average	Mode	Standard deviation	
1. Environmental conditions of aquaponics	4.75	5	0.45	4.86	5	0.36	
2. Aquaponics resource conditions	4.5	5	0.67	4.57	5	0.51	
3. Conditions of aquaponics industry	4.25	5	0.75	4.21	4	0.58	
4. Technical conditions for aquaponics	4.33	4	0.65	4.07	4	0.73	
5. Aquaponics policy conditions	3.75	4	0.75	3.57	4	1.09	Deleted
1-1. Climatic conditions：Suitable climate of light, rainfall	4.25	5	1.35	4.57	5	0.51	
1-2. Environmental load bearing：Whether the environment has sufficient load capacity	4.16	4	0.71	4.43	5	0.76	
1-3. Negative Impact：negative effects of the environment	4.08	4	0.79	3.93	4	0.83	
1-4. Economic environment:The willingness of local businesses or fisherman to invest capital	4.16	4	0.57	4.43	4	0.51	
1-5. Social environment: the willingness of local businesses or fisherman to invest	4.16	4	0.71	4.36	4	0.50	

1-6. Laws and regulations：whether there are relevant laws and regulations for aquaponics	3.83	4	0.93	3.5	4	1.05	Deleted
1-7. The effect of pests on aquaponics				3.79	4	1.05	
1-8. The degree of close integration with actual cases				3.93	4	0.47	
2-1. There are available water resources including river reservoirs	4.25	4	0.62	3.93	4	0.83	
2-2. With excellent water quality	4.75	5	0.45	4.43	5	0.94	
2-3. Available fish pond pond rice field open house factory	3.41	3	0.66	3.57	3	0.65	Deleted
2-4. Rivers, highlands, lakes and reservoirs available or rented	3.58	4	0.51	3.64	4	0.74	Deleted
2-5. The industrial park promoted by the government	3.75	4	0.62	3.79	4	0.70	Deleted
2-6. Having available economic fish species	4.33	5	0.77	4.57	5	0.51	
2-7. Having available aquatic economic plant species	4.5	4	0.52	4.14	4	0.53	
2-8. There are available plankton species	4	4	0.60	3.79	4	0.43	
3-1. Enterprise or fisherman's funds： capital invested by enterprises or fishermen themselves	4.16	4	0.71	4.29	4	0.47	
3-2. Financing by enterprises or fishermen：bank loans available to enterprises or fishermen	4.16	4	0.57	3.93	4	0.47	
3-3. Industrial development fund：aquaponics industry development fund was provided to support the development of new varieties and technologies	4.58	5	0.51	4.36	5	0.93	
3-4. The labor market: there is an abundance of labour in the area	3.83	4	0.71	3.43	4	0.85	Deleted
3-5. Introduction of talent: supplement enterprises or fishermen lack of talent	3.91	4	0.66	3.71	4	0.61	
3-6. Technical training: improve the scientific quality of enterprises or fishermen	4.08	4	0.66	4	4	0.39	
3-7. Technology of production:The region has complete production technology and knowledge	4	4	0.95	3.71	4	0.73	
3-8. Improve science and technology services: technology services available	4	4	0.85	4.07	4	0.62	
3-9. Industry-university-research：research institutes that can coordinate cooperation	4	5	0.95	4.07	4	0.73	Deleted
3-10. Mechanism of operation: enterprises or fishermen have effective operating mechanisms	4.41	4	0.51	4.07	4	0.62	
3-11. Business model：enterprises or fishermen have a unique business model	4.33	5	0.77	4.07	4	0.83	
3-12. Supply chain： the region has a complete supply chain	4.33	4	0.65	4	4	0.68	
4-1. Water quality control: complete technology and knowledge of water	5	5	0	4.71	5	0.61	

temperature dissolved oxygen nutrient control or operation						
4-2. Water pollution control: have the generated water pollution control or operation technology and knowledge	4.58	5	0.51	4.57	5	0.85
4-3. Breed of animal: have the right breed of animal	4.5	5	0.52	4.43	5	0.65
4-4. Density of breeding: with a suitable proportion of breeding density	4.33	4	0.49	4.14	4	0.77
4-5. Pathological treatment of animals: have the ability and knowledge to treat and restore pathological management	4.41	5	0.66	4.36	4	0.50
4-6. Animal environmental treatment: ability and knowledge to resist environmental change	4.41	4	0.51	4.29	4	0.83
4-7. Varieties of plants: with suitable plant varieties	4.33	5	0.77	4.79	5	0.43
4-8. Density of planting: with a suitable proportion of planting density	4.16	4	0.57	4.14	4	0.77
4-9. Pathological treatment of plants：have the ability and knowledge to treat and restore pathological management	4.25	5	0.75	4.14	4	0.77
4-10. Plant environmental treatment：ability and knowledge to resist environmental change	4.25	4	0.45	4.21	4	0.89
4-11. Varieties of microorganisms：have the right microbial variety	4.33	4	0.65			
4-12. Symbiosis of bacteria and algae：ability and knowledge to develop bacterial and algal symbiosis models	4.33	4	0.65			
5-1. Whether there is money available for grants, awards or coaching	4.5	4	0.52	4.21	4	0.70
5-2. Whether there are demonstration bases and industrial parks	4	4	0.60	3.86	4	0.77
5-3. Whether it has technical support for cold chain preservation of agricultural products	4	4	0.74	3.86	4	0.77
5-4. Whether it has fiscal, tax and financial support policies	4.25	4	0.62	3.93	4	0.73
5-5. Whether there is a specialized organization to carry out supervision and management activities	4.08	4	0.66	3.93	4	0.73

5-6. Carry out planning, supervision, control and management activities	4.08	4	0.51	3.64	4	0.63	
5-7. Whether there are laws and regulations fo aquaponics	3.83	4	0.71	3.57	4	0.94	Delete
5-8. Whether there is an aquaponics sustainable development policy	4.16	4	0.57	4	4	0.88	
5-9. Economic construction should be carried out under the conditions of protecting the environment and sustainable use of resources	4.33	4	0.65	4.29	4	0.61	
5-10. Whether it has an aquaponics recreational fisheries policy	4	4	0.60	3.86	4	0.77	
5-11. In the tertiary industry concept to develop aquaponics recreational fisheries	4.16	5	0.93	4	4	0.88	
5-12. We will adjust and optimize the structure of the food industry and establish a stable mechanism for ensuring input in food production	3.75	4	0.86	3.71	4	0.83	Delete
5-13. Take the scientific research of water-saving technology as the strategic goal of innovation	4.08	4	0.79	3.79	4	0.70	Delete
5-14. Take greening as the goal of innovation strategy	4.08	5	0.90	4.07	4	0.83	Delete

5. Conclusions

The important aspects of aquaponics turned out to be environmental and resource conditions, followed by industrial conditions and technical conditions, and finally policy conditions in this study. Experts were most concerned about the environmental conditions of aquaponics. In five dimensions and 48 indicators, an important sustainable implementation strategy was developed and the following recommendations were made: (1) Aquaponics as an important objective of rural revitalization policy, (2) various indicators are taken as the basis for policy implementation, and (3) an aquaponics promotion team is required.

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References

1. Gooley, G.J.; Gavine, F.M. Intergrated agri-aquaculture systems: a resource hand book for Australian industry development. *Rural Industries Research and Development Corporation* 2003.

2. Xu, W.; H, B.C. Research on China's aquatic product price fluctuation : Analysis of background factors based on consumption ratcheting and fishery transformation. *Price: Theory Practice* **2019,** (2):72-75.
3. Zhang, Y.; Zhao, L.A. Comparative study on consumption demand of Chinese and American aquatic products and its implications. *Journal of Ocean University of China* **2018,** (5):77-84.
4. Han, J.H. Study on the pollution of aquaculture wastewater and its treatment technology. *Agriculture and Technology* **2018**, 38 (12): 103-156.
5. Huang, C.; Gao, B.; Xu, S. etal. Changing phosphorus metabolism of a global aquaculture city. *Journal of Cleaner Production* **2019**, 225:1118-1133 .
6. Xu, Y.X. Research progress of biological treatment of aquaculture wastewater. *Journal of Zhejiang Agricultural Sciences* **2019**, 60(8):1306-1310.
7. Liang, X. M. Principle, method and ecological significance of aquaponics technology. *Science Breeding* **2018,** (03):60-62.
8. Li, J.l.; Lai, X.H.; Qi, Z.; Xiao, G.Q. Review of fish and vegetable symbiosis system. *Agricultural Technology & Equipment* **2020,** (04):120-122.
9. Ding, Y.L.; Zhang, M.H.; Zhang, J.H.; Yang, Q. Researches on fish and vegetable Co－existing system. *Journal of Fishery Sciences of China* **1997,** (S1):71-76.
10. Zhang, M.H.; Ding, Y.L.; Yang, Q.A. Study on fish and vegetables co-exsisting technique and system engineering. *Journal of Modern Fisheries Information* **2004,** (04):7-12.
11. Rakocy, J.E.; Hargreaves, J.A.; Wang, J.K. Techniques for Modern Aquaculture. St JosepmH, Michigan USA: *American Soc iety of Agricultural Engineers* **1993**:112-136.
12. Song, H.Q.; Guan, C.W. et al. Research Progress of Fish Vegetable Symbiosis Integrated Production System Mode. *Anhui Agricultural Science Bulletin* **2018**, 24(20):63-65.
13. Yep, B.; Zheng, Y. Aquaponic trends and challenges-A review. *Journal of Cleaner Production* **2019,** 228:1586-1599.
14. Rao, W.; Yang, W.Z.; Wei, Y.G.; Li, D.L. Temporal and Spatial Variability of Water Dissolved Oxygen with Influence Factors in Aquaponics System. *Transactions of the Chinese Society for Agricultural Machinery* **2017**, 48 (Sl) : 374-380.
15. Rakocy, J.E. The status of aquaponics. *Aquaculture Magazine* **1999**, 25:64-70.
16. Rakocy, J.; Masser, M.; Losordo, T. Recirculating Aquaculture Tank Production Systems: Integrating Fish and Plant Culture. *Southern Region Aquaculture Center Publication* No. 454:Mississippi State University, 1992.
17. Sanders, D.; Murtry, M. Fish increase greenhouse profits. *American Vegetable Grower* **1988**, 2:32-33.
18. Zhong, G. Research on the Dike System in the Pearl River Delta. *Beijing: Science Press*, 1987.
19. Fang, Z.G. Modern soilless cultivation techniques. *Tropical Crops Research* **1992,** *(02):70-78.*
20. Ding, Y.L.; Lan, Z.Q.; Zhang, M.H. Aquaculture sewage resources of industrialized closed circulating system-a typical eco-circulating economy model "fish and vegetable symbiotic system" . *Chinese Fishery Economy* **2010**, 28(01):124-130.
21. Li, D.H. A good model of new model of aquaculture combination in circulating water fishery. *China Fishery News*.
22. Yin, C.B.; Zhou, Y.; Liu, L.H. Theory and practice of recycle agriculture in China. *Chinese Journal of Eco-Agriculture* **2013**, 21(01):47-53.
23. Ding, X.T.; Zhang, Z.H.; Jiang, Y.P. Application prospect of aquaponics technology in urban families. *Acta Agriculturae Shanghai* **2015**, 31(06):150-153.
24. Xia, Q.; Xu, X.Q.; Liu H.Y. Exploration and practice of aquaponics breeding technology. *ShangHai Agricultural Science and Technology* **2018,** (05):121-122.
25. Heinsbroek, L.; Kamstra, A. Design and performance of water recirculation systems for eel culture in Japan and Europe. *Aquacultural Engineering* **1990**, 9 (3) : 187-207.
26. Love, D.C.; Fry, J.P.; Li, X.M. Commercial aquaponics production and profitability: Findings from an international survey. *Aquaculture* **2015**, 435 (67-74.
27. Blidariu, F.; Grozea, A. Increasing the Economical Efficiency and Sustainability of Indoor Fish Farming by Means of Aquaponics - Review. *Lucrritiinificezootehniei biotehnologii* **2011**, 44 (2) : 1-8.
28. Kaparang, F.E.; Matsuno, Yamanaka. Studies on underwater sounds produced by yellowtail Seriola quinqueradiata. *Fisheries Science* **1998**, 64 (3) : 353-8.
29. Goddek, S.; Delaide, B.; Mankasingh, U. Challenges of Sustainable and Commercial Aquaponics. *Sustainability (Basel, Switze rland)* **2015**, 7 (4) : 4199-224.
30. Lawrence M. kahn. Wage inequality, collective bargaining, and relative employment from 1985 to 1994: evidence from fifteen OECD countries. *Review of Economics and Statistics* ***2000**, 82(4):564-579.*
31. Hong, Y.T. Quantitative analysis and performance evaluation, compiled by the research and development assessment committee of the executive yuan, and selected discussion on the performance evaluation of the administrative plan (III).

32. Dunn, W.N. Public policy analysis : an integrated approach. Sixth Edition. New York : Routledge, 2017.
33. Chen, G.W. Research on urban competitive advantages evaluation system. Doctoral thesis, Urban Planning Institute, National Success University, Tainan, 2002.
34. Lin, J.J. Research on the construction of the brand management effectiveness evaluation index of the technical college. Master's thesis, Institute of Education Policy and Administration, Jinan International University, Nantou, 2004.

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