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Quality Management Practices of Intensive Whiteleg Shrimp (*Litopenaeus vannamei*) Farming: A Study of the Mekong Delta, Vietnam

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Abstract: Continuous warnings on quality and food safety of shrimp products from importers have led to increases in port rejections. This has increased awareness amongst Vietnamese farmers for conducting shrimp farming according to specific certification guidelines. The purpose of this paper is to clarify the situation of quality control and effectiveness of Good Aquaculture Practices (GAP) in Vietnam (VietGAP) for intensive shrimp systems by making a comparison between VietGAP and non-GAP applied farms. The farmers in the GAP system performed well on seven control points related to quality management, especially regarding reservoir construction, water monitoring, and chemical use. Of the farms, 49% reported disease, and the ratio of safety rejections was low. The farmers in non-GAP farms appeared to have weak practices in quality control with high usage of antibiotics, leading to 64% of farmers reporting disease and 20% of tested shipments being rejected. The VietGAP applied system has the potential to deal with disease and quality problems to increase export opportunity for *Vannamei* shrimp. However, VietGAP does not generate a high price premium in itself because it is not a recognized certificate in the global markets. The results reinforce previous findings regarding eco-certification and how it can be a useful tool to reduce small-scale producers' risk, even though it does not necessarily generate a price premium.

Keywords: diseases; eco-certification; food safety; *Litopenaeus vannamei*; quality management; VietGAP; whiteleg shrimp

1. Introduction

Vietnam's aquaculture is a large and world-renowned industry, producing 4.3 million metric tons (MT) with an export value of 9 billion USD. This is predominately due to aquaculture of the *Pangasius* catfish and shrimp farming. According to the Ministry of Agricultural and Rural Development (MARD) [1,2], the Vietnamese shrimp farming industry has achieved remarkable growth in production and export value from 47,100 MT in 1995 to 762,000 MT in 2018. The industry stretches over 736,000 hectares (ha), and the product is consumed in over 90 countries.

The Mekong Delta (MD) is the most important commercial shrimp farming area, where more than 93% of the shrimp culture occurs and from which 82% of total production comes [3]. The shrimp industry has a history stretching back to the early 1990s. The technology has developed, and one of the most recent methods is the intensive system. Intensive farming makes up only 5.6% of shrimp farms, but has high productivity of 8–10 MT per ha. Whiteleg shrimp *(Litopenaeus vannamei)* is the most predominantly farmed species in the MD with such a system. The shrimp is mainly exported to highly sophisticated quality- and safety-conscious international markets.

The industry structure consists mostly of fragmented small-scale producers. The small-scale sector represents 80% of the total number of shrimp farmers, and they contribute more than 80% to the total production [4]. In 2006, approximately 330,000 households had shrimp farming operations, and of these, only 79,600 practiced intensive systems. Intensive systems have a pond area ranging from 0.2 to 0.7 ha [3–5]. Unfortunately, the Vietnamese shrimp sector has witnessed major problems since the introduction and growth of the intensive system. The most prominent issues are regarding higher disease outbreaks and high port rejection rates from importers [6] Rejections happen because the food and safety qualifications, which differ between importers, are not met by the farmers, meaning that the products do not have the appropriate standard. Disease outbreak has resulted in growing debt amongst farmers as income comes to a halt due to more failing harvests [7]. Shrimp disease caused a loss of 28–50 million USD for the MD in the 2000s. This caused many farmers to give up production and abandon their farms [8]. Farmers who continued production responded to the increase in disease outbreaks with a higher use of chemicals, including antibiotics, and unintentionally created the problem of pesticide/drug residues in the final products [9]. Recently, Vietnam has received warnings of violations of food safety from the importers. Vietnam's number of rejections was high between 2006 and 2010 compared to other countries, ranking third in Japan, sixth in the United States, and eighth within the European Union (EU) (Figure 1). Regarding million USD of imports, Vietnam ranks top in average rejection rate in the Japanese market at 13% per million USD of imports and ranks ninth in the EU market at 15% per million USD of imports [10].

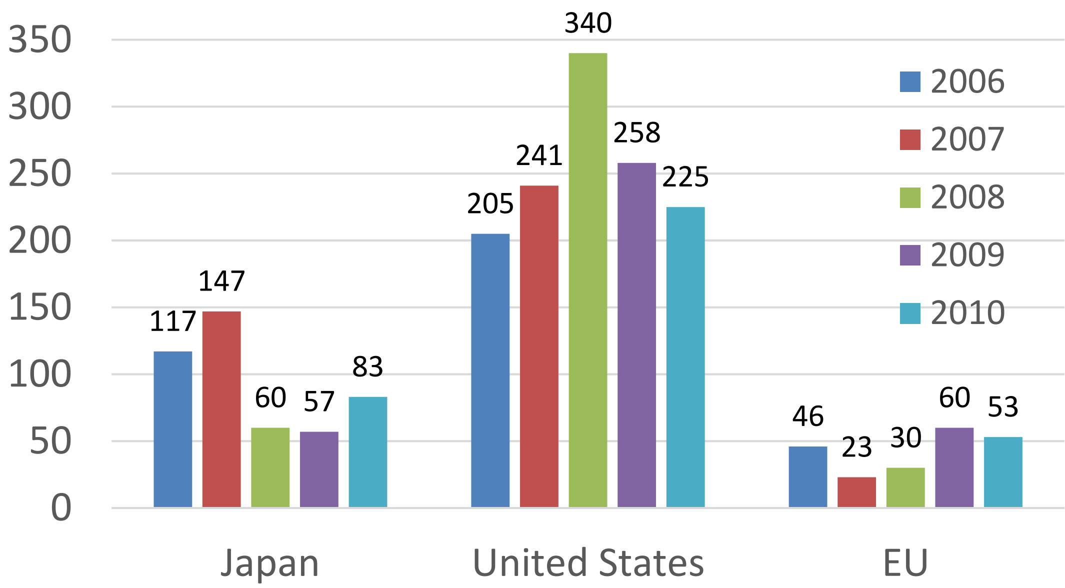

Figure 1. Number of rejected shipments of Vietnamese fishery products intended for export from Vietnam to Japan, the United States, and the European Union (EU), 2006–2010 (numbers in cases). (Source: UNIDO IDE, 2013).

A detailed look at reasons for rejections across these markets reveals that Vietnamese fishery products are rejected for various reasons, depending on the market. The numbers in Figure 1 and Table 1 illustrate that there are various weak links in the supply chain of Vietnamese fishery products. Bacterial and other contaminations, pesticide residue, hygienic conditions/controls, and veterinary drug residue are not well controlled or tested throughout the supply chain [10]. At the production stage, usage of antibiotics and other chemicals is not well controlled. This leads to overuse, which again leads to the detection of these chemicals in the final product in the shrimp's body parts, such as in the tail and hepatopancreas [11]. This suggests that most contamination that is detected in the product is possibly present throughout the production stage. International standards demand different certifications, and Vietnam is struggling to keep up with them. Some shrimp farmers have started to get involved in certification applications in order to improve food and safety control for the product [12–14]. In Vietnam, a number of shrimp farmers have sought to improve food safety by culturing shrimp according to the Good Aquaculture Practices (GAP) in Vietnam (VietGAP), while others still practice intensive farming without any certification [15]. The number of shrimp farmers who have given up farming according to VietGAP is increasing, notwithstanding efforts of functional branches to maintain the certification. There are many reasons behind that issue. The appropriate farming practices for disease control and quality management in the VietGAP system have not been fully identified or fully understood by farmers [15,16]. Therefore, the objective of this paper is to clarify the status of disease outbreak control and quality management between VietGAP and non-GAP systems as reported by shrimp farmers.

Table 1. Reason for rejection of Vietnamese fishery products in the US, EU, and Japan markets.

Reasons	US	EU	Japan
Bacterial contamination	**961**	**127**	**145**
Other contaminants	**209**	**24**	**1**
Additives	120	33	32
Pesticide residues	**0**	**4**	**50**
Adulteration/missing document	103	7	0
Hygienic condition/controls	981	20	23
Mycotoxins	-	0	7
Packaging	0	2	2
Veterinary drug residues	**170**	**172**	**297**
Labeling	349	2	0
Heavy metals	0	61	0
Other	21	32	6
Total	2914	484	563

(Source: UNIDO IDE, 2013).

2. Materials and Methods

2.1. Theoretical Review

Aquaculture is one of the greatest growing global food production systems. Wild capture is becoming more regulated; this is expected to lead to a reduction in the caught biomass, and aquaculture is expected to close the forecasted global deficit in fish protein by 2020 [17]. The rapid expansion of this sector exposes a wide range of concerns about its social and environmental impacts, including water pollution and degradation of the surrounding environment [6,18]. There is a pressing demand in the global seafood market for sustainable aquaculture. This understanding reviews the key trends in the international market that drive the development of sustainability requirements and the emergence of certification as a prominent strategy to meet such requirements [14,19]. Many academic studies have shown the impacts of voluntary standards and certifications for production. Dilley, Peyser, and Kennedy [12] comment on changes in the quality and resilience of ecosystems, resource efficiency, and livelihoods, as well as social welfare within the workplace and wider community. The voluntary certifications give information on safety, welfare, traceability, and sustainability [13]. In the certificate, a measure of quality is that the product is without antibiotics and pesticides [14]. The majority of sustainability certifications bring a possibility for economic benefits due to the change in market price, profit margin, access to different markets, and improved reputation; therefore, the revenue is changed [19,20]. However, the levels of change in price and profit margin because of national certifications like VietGAP were small, at 3% for price and 2% for profit margin (equaling 95 USD per MT), respectively, because customers are not willing to pay more for an internationally unrecognized certification [14,19].

VietGAP is an abbreviation for Good Aquaculture Practice in Vietnam—a national standard applied in aquaculture to provide insurance for the farming of safe and hygienic products, while reducing disease and pollution in the environment and promoting animal health and social responsibilities, as well as the traceability of products [21]. The VietGAP standard was first established in 2008. It was created with the Food and Agriculture Organization's (FAO's) Technical Guideline for Aquaculture Certification and the Association of Southeast Asian Nations (ASEAN) shrimp GAP (10 GAPs for ASEAN countries), as it has instructed member countries to establish their own national GAPs [19,22]. There are four modules under the ASEAN GAP, i.e., quality products and food safety, disease reduction, environmental safety, and social safety and welfare. Each country in the ASEAN GAP is required to meet the food safety module at the first step and to be benchmarked with each other step, therefore making the 10 GAPs compatible with each other.

As for the commercial brackish shrimp culture, VietGAP sets guidelines consisting of five principles, 24 control points, and 45 compliance criteria, which are meant to cover a wide range of farm management issues.

- **Principle 1**: *Legislation—includes six control points with 10 compliance criteria*.
- **Principle 2**: *Food safety and quality—includes four control points with 10 compliance criteria*.
- **Principle 3**: *Animal health and welfare—includes six control points with 11 compliance criteria*.
- **Principle 4**: *Environmental integrity—includes four control points with seven compliance criteria*.
- **Principle 5**: *Socio-economic aspect—includes four control points with seven compliance criteria*.

The issued guideline covers 26 pages of main content and 12 pages of appendices. The original document is Decision No. 4835/QĐ-BNN-TCTS approved on 24, November, 2015 by the MARD (in Vietnamese). The clear emphasis on food safety and disease control is in Principle 2, Principle 3, and Principle 4. Shrimp farms have to consider control points mentioned in the VietGAP, with seven control points that must have been taken care of pre-harvest, including seed and stocking, feeding, water monitoring, chemical/pesticide usage, reporting of disease to authorities, sanitation, etc. with the guidance of compliance criteria (Table 2).

Table 2. Brief explanation of control points [1] regarding shrimp health and safety in Good Aquaculture Practices (GAP) in Vietnam (VietGAP).

Control Points	Principle [2]	Compliance Criteria *
Farm and pond sanitation/hygiene pre- and post-culture	Prin. 2 Prin. 3 Prin. 4	Farm sanitary activity must be done before releasing Post-Larvae (PL). Predator control: Use equipment, chemicals, and instruments during pond preparation; preventive methods such as purse seines, puppets . . . Dredged bottom sludge—after harvesting. Farm must apply disinfection procedures and/or allow appropriate fallowing periods between harvests and re-stocking (30 days minimum). Separate grow-out ponds apart from living area, prominent locations with clear signs (with illustrations). Assessment of hazards to food safety can be done once a year by self-evaluation or by a consultant.
Seed and stocking	Prin. 3	Certified hatchery; documents related to seed purchasing must be kept and recorded. Transportation time: Does not exceed 8 h. Size: PL12–PL15 (9–11 mm in length); density: 40–150 PLs/m^2; Negative results for white spot, yellow head, Taura syndrome, slow growth syndrome, and other new infectious diseases with a document announcing testing.

Table 2. *Cont.*

Control Points	Principle [2]	Compliance Criteria *
Feed use and feeding regime	Prin. 2 Prin. 3	Dosage and feeding based on producers' instructions or guidelines from professional staff with systems to ensure the amount of feed given in accordance with the needs and appetite. Feeding monitoring systems in place could be feeding trays or visual observation. Storage in solid shed; inspection monthly, expired products are not used. Actively adjusting the pellet dosage size to the age of the shrimp. All the related information on feed and feeding must be recorded.
Water use	Prin. 2 Prin. 3 Prin. 4	Check quality of in-take, in-pond, and discharge water by themselves or services regularly or based on results of authorities. The list of water quality indicators that need to be checked was provided with guidelines (temperature, salinity, clarity, dissolved O, pH, alkalinity, NH_3). Tap water and groundwater should not be used to reduce salinity in rearing ponds. Making records of water quality test results. Reservoirs have to account for at least 15% of the area. Discharge water is not allowed to discharge directly into the river or irrigation system to avoid contamination of the water supply system.
Drug/chemical use	Prin. 2 Prin. 3	Only use products (especially antibiotics) approved by the relevant competent authority. Using limited products: Stopping use at least two weeks prior to harvest for normal chemical compounds and earlier for veterinary drugs. Dosage based on producers' instructions or guidelines from a professional. Stored in a secure lockable store and under conditions. Expired products are discarded in an appropriate manner and recorded. Medicines, chemicals, and probiotics in stock must be listed and periodically checked on a certain day of the month. In the case of using anti-biotics: + Only use when identifying shrimp bacterial diseases. + Must follow the treatment regimen of professional staff. + Do not use anti-biotics for prophylactic use or to stimulate growth. + Discontinue use as recommended by the manufacturer.
Collection, classification, and dissolving of farming wastes and diseased shrimp	Prin. 2 Prin. 3	Wastes: + Tabulation of waste classification. + Collecting and storing wastes/garbage according to specific types in safe and specialized containers. + Waste treatment must be done in a timely manner and clearly. + Hazardous wastes must be dissolved or returned to suppliers. + Do not bury expired products; do not burn solid waste on the pond banks. Diseased shrimps: + Do not discharge infected water to the environment without treatment. + Once dangerous disease breaks out, farmers must announce it to the veterinary agency and adjacent farmers to prevent spreading. + Dead shrimp should be removed and documented. + The veterinary staff of the commune must be informed as soon as any epidemics occur.
Harvest and transportation	Prin. 2	Harvest and transportation are undertaken in an appropriate manner to ensure food safety; this is the responsibility of the farmer. Documented harvest and transport are in place where applicable.

[1] Control Points: Checkpoints that are necessary to manage production processes. [2] Principle: Statements describing the philosophical basis for production of a product and are aimed at guiding stakeholders. Principles can include sets of criteria that provide more details on how to achieve requirements. * Compliance Criteria: A desirable state of farm management for each control point, and it is an objective criterion for evaluation. (Source: Synthesized from the Decision of the Guidelines for application of VietGAP issued by the Ministry of Agriculture and Rural Development, 2015).

The VietGAP certification could be obtained either for a group or for an individual. However, there are perceived limitations for small-holders in terms of the high transaction cost and low market competition. Without a better financial incentive, it becomes harder and less desirable for small-holders to pursue VietGAP [23]. The FAO-recommended cooperative approach and collective action help in the governance of small-scale aquaculture and fisheries [24]. Individual certification will be awarded to separate farms that submit evaluation applications themselves after the official audit. The VietGAP group standard is issued for groups of farmers organized under collective forms, such as cooperatives *(Hợp tác xã)* or small-farmer clusters *(Tổ hợp tác)*. This means that a group of farmers who are listed in the member list of the cooperative will own a common certification. The certification is issued by an authorized certifier and is granted after all members of the cooperatives or clusters undergo an auditing process. Cooperatives are collective economic organizations formed from seven or more individuals, households, and/or legal entities. The founders have mutual needs and receive the same benefits. They voluntarily contribute capital and labor to carry out certain work to increase production efficiency and improve the livelihoods of members. Clusters are defined as economic organizations based on a cooperation contract under authentication of a communal People Committee, which is formed by three or more individuals who jointly contribute capital and labor to carry out certain work for mutual benefit and responsibility. Clusters represent a lower level of organization and management than cooperatives [23,24].

2.2. Study Sites' Context

This study was conducted through face-to-face interviews with shrimp farmers in the Soc Trang and Ben Tre provinces located in the MD of Vietnam (Figure 2) [25].

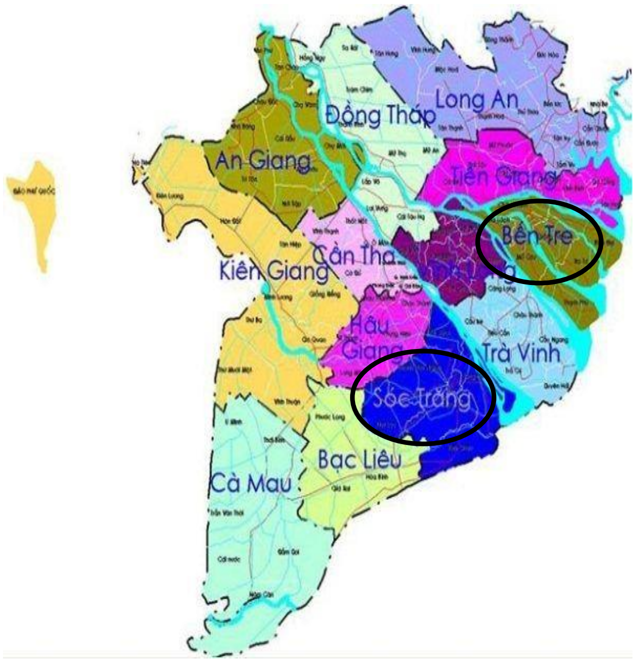

Figure 2. Map of the Mekong Delta illustrating the surveyed study sites in Soc Trang and Ben Tre. (Source: Vietnam Institute of Economics and Planning, 2015).

Soc Trang is one of the largest commercial-shrimp-producing areas in the MD with its contribution of 134,184 MT over 54,098 ha in 2018. The Department of Fisheries (DoF) of the province has made considerable efforts in organizing shrimp farmers into cooperatives and clusters, according to the policies of encouraging collective economy from the government. The province currently has 27 established cooperatives with 1218 members over 2784 ha, as well as 174 clusters with 3262 members over 3341 ha. Until 2013, the Project of Coastal Resources and Sustainable Development (CRSD), funded by the World Bank, was widely deployed in the MD, aiming to improve application of the VietGAP standard. Soc Trang province is one of the pioneer provinces in farms that are involved in application of VietGAP. Currently, there are approximately five shrimp cooperatives that have acquired VietGAP certification, and many other cooperatives/clusters are being supported to obtain VietGAP [26].

Ben Tre province is located on the other side of the MD. This is where individual shrimp farms with non-GAP application are presented. Shrimp farming here is usually organized by clusters rather than cooperatives, as the policies of collective economy are relatively inefficient. The reason comes from the small-scale farming (less than 0.5 ha/farm) dynamic and prompts an increase in intensive whiteleg shrimp farming. The numbers of shrimp farming households change continuously and are nearly impossible to keep track of. The total area of shrimp farming has been rapidly expanding in this region, with the current figure being 35,000 ha. The region has a production of 55,000 MT, where whiteleg shrimp production makes up 86.3%. This rapid increase in shrimp small-holders is correlated with greater disease outbreaks and lower quality of shrimp for the province of Ben Tre [27].

2.3. Data Collection and Analysis

The method of data analysis is a combination of qualitative and quantitative methods. The research was carried out with two mass surveys given to shrimp farmers in the intensive horticultural system using semi-structured questionnaires in the Soc Trang and Ben Tre provinces. The first interview was conducted between March and April 2018 and the second was carried out within the period February to March 2019, after the harvesting of the main production crop. The initial total of respondents was 212; after refining and removing substandard samples, the number of samples remaining was 204. The results showed that 104 farmers follow VietGAP guidelines for their plots, and 100 follow non-GAP guidelines, ensuring comparisons between the practices of the two systems. Local officers provided an official list of farmers as potential respondents. The first respondents were chosen from a list provided by authorities. The first respondents would then be asked to introduce the next respondents, and so on. This is the so-called "snowball" sampling method. Farmers would answer questions based on their own experience. The questions were presented to limit responses to information from the past six months. This was to diminish the possibility of error, as most farmers do not have well-documented practices, and information prior to six months could thus not be trusted. The information on household characteristics and crop management practices relied on controlled points of VietGAP and non-GAP recorded in parallel (this was introduced in Section 2.1). The survey data allowed researchers to quantify factual differences between those applying and those not applying the VietGAP standard.

Throughout the field trip, annual reports were collected and senior specialists from local authorities were interviewed (i.e., DoF) (in a so-called Key Informant Panel—KIP interview) in order to learn more about the current situation, motivations and constraints they experienced in shrimp culture, and VietGAP compliance amongst farmers. The quantitative analysis made it possible to statistically compare differences between the required practices and actual practices of the two systems, while qualitative analysis employed action explaining possible differences.

3. Results

3.1. Respondents' Data

The characteristics of respondents are shown in Table 3. The majority of respondents were males of middle age. Farmers in the VietGAP system belong to aquatic cooperatives or aquaculture clusters. The household size of the VietGAP system was smaller than that in non-GAP system, but the number of people who worked on shrimp farms tended to be higher in the VietGAP system. The reason was the correlation between labor use and farming size that will be analyzed in the next section. Although farmers in the VietGAP system had a long experience of shrimp farming at 16 years, the intensive model developed in recent years when the artificial seed production of whiteleg shrimp was boosted in the central region of Vietnam, and was subsequently popularized in the MD. The average number of years of education was 8.37 years, with the majority of them having junior high school as their highest level of education. In Vietnam, the standard educational system covers 12 years. Farmers in the non-GAP system had individual farms with shrimp farming experience ranging from eight to twelve years. As the new development of the shrimp industry in the province, they operated intensive models of farming *Litopenaeus vannamei* for around five years. They had a relatively high education level at an average level of 11. These numbers show that shrimp farmers in the non-GAP system are likely amateurs approaching aquaculture certification.

Table 3. Respondents' profile.

Variable	VietGAP	Non-GAP
	Sample = 104	**Sample = 100**
	Mean (and Stdev.)	**Mean (and Stdev.)**
Gender (Male/Female) (%)	75/29	78/22
Average age (Years)	50 ± 11.5	49 ± 9.2
No. of family member	3.96 ± 1.21	4.4 ± 1.46
No. who worked on shrimp farm	2.28 ± 0.81	1.58 ± 0.57
Shrimp experience (Years)	16.5 ± 6.6	10.1 ± 4.1
Intensive model experience (Years)	8.0 ± 6.8	5.3 ± 3.0
Years of schooling (Years)	8.7 ± 4.5	10.9 ± 5.3
VietGAP Certificate awarded officially (%)	32.5	None

(Source: Author's survey, 2019).

The farmers wanting VietGAP certification had applied for several years—three to five—and only 32.5% of them had been awarded certification. The low numbers were due to the high cost of the application and the lack of governmental support to pay it. In addition, there was no specific premium for GAP products. VietGAP certifications in some of the cooperatives had expired (valid for two years). Others are practicing shrimp farming according to the VietGAP standard but have not been awarded the certification.

3.2. Quality Control Practices in Shrimp Farming

3.2.1. Practices of Control Points Related to Quality Terms in the VietGAP System

A significant number of the farmers were smallholders (land area averaged 0.9 ± 0.62 ha), as seen in Figure 3. An average of 71.05% of the above area was used for stocking shrimp. The rest was used for constructing warehouses, reservoirs, and treatment ponds. Each farm normally operated two or three grow-out ponds, with a mean pond size of 2568 ± 1080 m^2. The survey shows that pond depth was 1.18 m, and 92% of farms built reservoirs with a sharing area of 22%, meeting the requirement stated in VietGAP (at least 15% of farm size). Reservoirs are necessary for areas where high turbid water is located and for overcrowded farms, where intake and outfall are from the same source [28]. Most farms had solid warehouses to store and maintain the quality of feed sacks, chemical compounds, and other input materials. This information shows that most farms in this system follow very similar farming practices of quality control; this includes control points as follows in Figure 3.

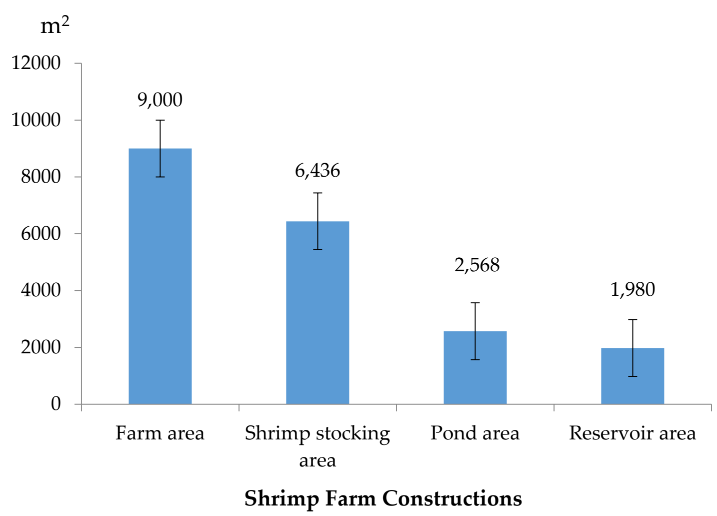

Figure 3. Distribution of land usage for shrimp farms in the VietGAP applied system. (Source: Author's survey, 2019).

Actions for pond preparation are an essential stage for the reduction of disease outbreaks and providing clean products without contamination [29,30]. More than 52% of farmers rake and plow the bottom to aerate the soil every two production cycles or after diseased infected cycles, instead of after every cycle, as demanded by VietGAP. Farmers then fried and compacted within two weeks to eliminate residual germs. More than 96% of farmers ensured breaking time (at least 30 days) of pathogen cutting before stocking the new cycle. Most farmers complied fully with the principle of rehabilitation, disinfection, wastewater treatment, and breaking time between the two crops.

The farmers attribute poor seed quality and unappropriated stocking management to the crop failures and difficulties in disease and quality control [29]. Up to 89.7% of respondents could choose virus-free post-larvae (PL) (with tested authorized documents) from local hatcheries, which were assigned through contracts by cooperatives. Farmers reported that common diseases caused by viruses, such as the White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), and slow growth syndrome, were compulsorily tested in these authorized hatcheries. Shrimp were stocked at a density of 39 ± 14.8 PL/m^2 at the appropriate size of 12 (equal to the length of 9–11 mm). All farmers reported ideal stocking density (70–120 PL/m^2) and strictly followed the advised shipping time (<8 h), even though 10% of farmers stocked below the recommended density (<40 PL/m^2).

Good feeding management—not only the feed quality but also feeding regime—is essential in quality control, as it directly impacts water quality [16]. The cooperative has shown its role in collaboration with feed suppliers through contracts for feed supply with companies or level 1 agents (57.3% of respondents) in order to ensure the quality, reduce cost, and receive technical guidance. Feed supply was always available, and, therefore, feed sacks were only kept up to nine days in the solid shed to neutralize the growth of harmful bacteria and mold. Farmers reported strong compliance to the feeding dose shown on the package. Hence, it is believed that they can produce commercial shrimp products with a high quality of meat, beautiful appearance, and non-soft shells. The manual feeding was done by using round feeding trays made out of net. The feed conversion ratio (FCR) was 1.11, and high FCR was observed for only 5% of the respondents. Farmers kept a diary, recording operations such as feeding and chemical use, which was beneficial for traceability. A high ratio of high-protein feed was reported (39.4%). Such feed is usually expensive and makes up a big part of the production cost. The total feed cost averaged 61.2% of the total investment cost (7426 USD/ha). Increasing protein ratio does not necessarily lead to better growth, but raises FCR and pollutes water.

In-charge water was obtained from natural canals, and then pumped into the reservoirs for chemical treatments and disinfection within 13 days to stabilize turbidity and achieve appropriate plankton density. Plankton density that is too high can lead to discoloration. Over 84% of farms regularly monitored in-pond water quality indicators, such as pH, dissolved oxygen, salinity, visibility, and temperature at optimum levels using toolkits/chemicals provided by the project aiming to encourage VietGAP application via the cooperatives. Some farmers took water samples to the inspection services (13.4%). Compensation for in-pond water was practiced (74% of respondents) rather than water exchange, with a frequency of 12 days/time and daily when shrimp reach one month of post-stocking. Around 14% of water was offset per time. Water compensation was stopped temporarily when diseases occurred in adjacent farms to reduce the risk of disease transfer across farms. The authorities took water samples regularly for checking specifications, and announced the results widely to help farmers monitor and adjust their actions. However, there were few warnings amongst farmers if they had disease outbreaks; they were thus ejecting contaminated water, which, in turn, could contaminate the water for other farms.

Pesticide and chemical use, such as the use of toxic heavy metals, antibiotics, and organochlorine pesticides, poses serious hazards to the quality of products. In particular, veterinary drug residue in the final product would lower its standard significantly. Farmers in the VietGAP system learned this lesson throughout multiple training courses and propaganda programs during the Coastal Resources for Sustainable Development—CRSD project. Therefore, farmers prioritized application probiotic compounds as recommended in the VietGAP standard; thus, no antibiotic use was recorded during the last surveyed crop. In the case of medicine usage, all of them had knowledge of the residue period and complied fully with the guidance. Only 30% of certain farms relied solely on chemical usage in disease treatment.

Within crop cultivation, a huge amount of waste, such as wastewater, bottom sludge, solid waste, and diseased or dead shrimps, was released. Farmers usually used chemical compounds for treating post-culture water before discharge (62.5% of respondents). However, 21% of farmers performed no wastewater treatment. Use of treatment ponds and stocking of tilapia to deposit waste matters and purify after-used water were done by 18% of respondents. Chemical containers, bottles, cans, paper, and plastic bags were classified as solid wastes, which were collected and burned by 85% of farmers. Whenever they found the value of recycling, they would collect and sell to traders of waste products. Half of the farmers disposed of bottom sludge correctly according to the VietGAP guideline by taking advantage of available land surrounding homes, like yards, rice fields, and orchards. However, half of the respondents disposed of the material incorrectly by placing it on the pond banks, giving it an opportunity to seep back into the pond during rains. No report of direct sludge discharge was available, but the illegal sludge discharge was observed during the field trips. This is direct evidence of poor practice and weakness in the reporting of illegal activity. Few farmers reported to authority when detecting infected shrimp, as is the guideline of VietGAP. They often firstly tried to deal with it by themselves. In the case of mass mortality, emergency harvesting was conducted. If diseases occurred early (less than one month post-stocking), they would leave the crops intentionally after proper decision-making.

3.2.2. Practices of Control Points Related to Quality Terms in the Non-GAP System

Since the government issued resolution No. 09/ND-CP to convert low-productivity agricultural areas to aquaculture, shrimp farming in the Ben Tre province has grown. The number of shrimp ponds has increased dramatically, but farms are mainly small-scale (less than 0.5 ha per farm) and scattered. Each farm operated an average farming area of 3806 ± 2765.6 m^2 (Figure 4). Normally, nearly 80% of the farm area was used for shrimp stocking. The farm size was usually accompanied by the allocation of the reservoir areas. Due to the limitation of land area, 25.5% of farms cultured shrimp without reservoirs, whereas 40% constructed very small reservoirs (less than 1000 m^2) that resulted in water being occasionally kept for disinfection. Farmers constructed temporary sheds, sometimes with small roofs, which could affect the quality of input materials. Grow-out ponds were designed with siphon pit (85%) or plastic lining (15%) to deposit suspended matters and remove bottom sludge more easily. Net fences were built embracing the ponds to protect shrimp from pathogen carriers and prevent biological predators from approaching the shrimp ponds, such as birds, frogs, crabs, and, in some cases, people.

Pond renovation, including bottom sludge removal, disinfectants, lining, and fertilization, was usually applied before each crop. However, bottom sludge was plowed only once a year for over 90% of respondents, unless there was a disease outbreak during the previous crop. Farmers generally dried the bottom prior to stocking. Starting the disinfection process seven to eight days before stocking did not give enough time for all pathogens to be removed; thus, the pond would not be sufficiently clean according to the recommendations of the certification. A total of 55/100 farmers guaranteed that their operation kept the minimum 30 day break between crops.

Quality of PL is very important in the success of shrimp culture, as it decides the harvest yield [29]. Although most farmers had knowledge of the importance of quality of PL and optimum stocking density, 22.2% of the farmers still chose lower-price PL without disease pathogen tests. They stocked at a high density with 92.6 ± 13.6 PL/m^2. Some farmers, 20%, were stocking above recommended criteria (more than 120 PL/m^2). Too high of a density could cause stress on the shrimp, and could be a cause of disease and harvest failure [16]. Seeds were stocked at the standard size of PL11. Size of PL is important, as small PL are less resistant to environmental agents and are prone to mortality during shipping, stocking, and especially rearing [30].

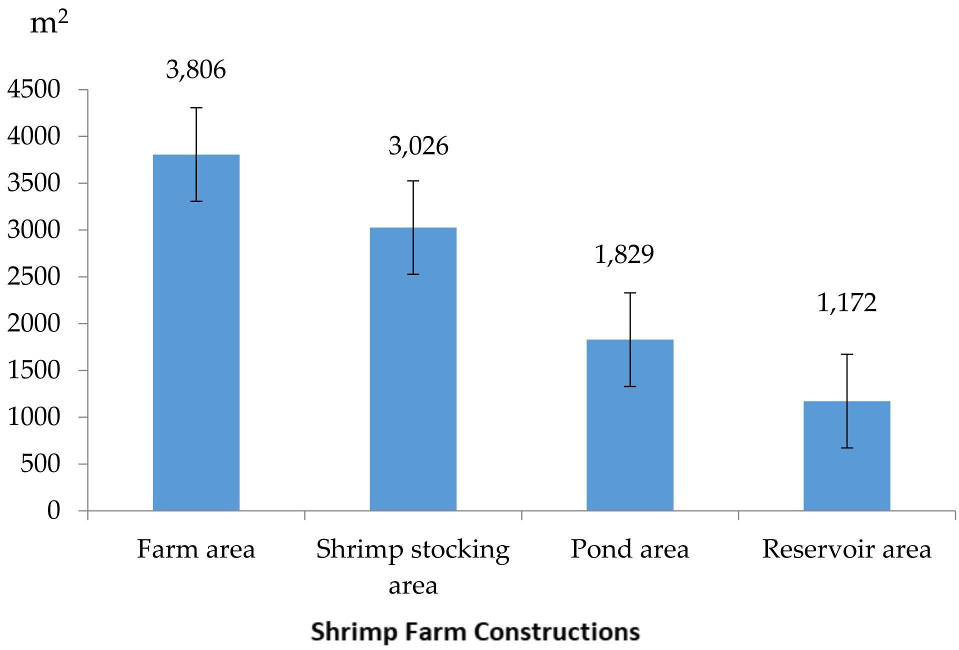

Figure 4. Distribution of land usage for shrimp farming in the non-GAP applied system. (Source: Author's survey, 2019).

Feeding control complied fully with the guidance shown on the feed-package. Feed supply was constantly available, thus eliminating the need to keep big quantities and minimizing the longevity of storing the feed. The average number of days of storage for the feed sacks was 5.23 days. Even though this is not considered a long period of time, the sacks were kept in simple sheds and in direct contact with the ground, which could cause the feed to mold and make it useless and even harmful for the shrimp. There were no specific criteria for FCR in any of the certificates; however, the higher the FCR, the lower the feeding efficiency. The average FCR was relatively high (1.21), and 14% of farmers reported overfeeding with very high FCR (>1.40). The feeding was mainly done manually by hand feeding (80%), and some used mechanical feeding machines (20%). Feed trays help farmers manage dosage effectively and adjust feeding amounts immediately. However, feeding machines were recommended because they works continuously throughout the day, so the shrimp can eat whenever and probably grow faster. The downside of using such mechanized feeding methods is that, if not properly controlled, it could lead to overfeeding and contamination of the water when feed goes uneaten. The farmers did not keep a record of the feeding process, thus making it hard to assess usage and effects of feed. Recordkeeping could be economically beneficial and save farmers money on unnecessary feed. It could also give the product better credibility by showing a better control of production.

Due to the limitations in reservoir construction, in-charge water was occasionally kept and treated in the reservoir. Water was obtained directly from the natural rivers or canals. Regarding in-pond water during farming, most farmers had to supply water to make up for water loss by evaporation or seepage. From one month post-stocking and onward, 15% of the water was added every 12–13 days. Over 70% of farmers monitored water quality indicators infrequently and by using visual aids combined with experience. In-pond algae/phytoplankton density was controlled insufficiently by 30% of the respondents, which could lead to discoloration of the final product. Staff from regulatory and authorized organizations rarely took samples to check and control water quality, leaving the farmers to rely on their own experience for monitoring.

It is clear that, in these farming practices, the more concrete use of agrochemicals contaminates the farm products. Chemicals were used not only for treatments, but also for disease prevention by 57.5% of respondents. There were no monitoring procedures for chemical use, although chemicals that would result in residue in the shrimp were prohibited. Noticeably, more than 30.5% of farmers reported the use of antibiotics to combat bacterial diseases, and 28.8% confirmed the use of banned antibiotics, such as ciprofloxacin, enrofloxacin, chloramphenicol, etc. Farmers did not know the proper dosage. Farmers had almost no records accounting for the usage, except for those who were obliged to keep track of it for traceability. It was reported that the use of antibiotics was stopped 13 days prior to harvest time, which is shorter than the undetectable level for several frequent types [15].

After-use water was stocked in another separate pond by 48% of respondents for depositing contaminants, organic matters that are rich in waste food, and metabolic products. More than 30% of respondents used chemical or probiotic compounds for disinfection, while the other 22% of respondents continued to release directly into natural canals. Farmers disregarded the treatment of solid waste and let it float into natural canals (93%). Farmers seemed to be of the belief that the amounts of solid waste released from their farms were very small, and that the environment would be able to dispose of it naturally. Generally, 81% of farmers practiced correct disposal of bottom sludge by using small ponds or trenches and utilizing available land. With the aim of minimizing financial loss and mass mortality in the situation of disease outbreaks, 8% of respondents harvested shrimp immediately if the shrimp had reached commercial size. The others destroyed small-size shrimp or used chemicals to treat infected biomass. These ways were decided by farmers and with concern for the immediate problem, and not the authorities' guidelines. Therefore, a similar situation of little disease declaration hit the authorities, like with the VietGAP system. That was because the farmers did not believe in the proposed solution from the authorities over their infected ponds.

3.3. Situation of Disease Outbreaks, Food Safety, and Shrimp Quality

3.3.1. Situation of Diseases as Reported by Farmers

Products from diseased shrimp usually do not meet requirements for exports in terms of quality and food safety [19]. Red Body Disease and Hepatic Disease were the most prominent disease problems for farms in the VietGAP system, as shown in Figure 5. The data were collected based on farmers' responses on the last concluded production before the interview. The x-axis shows the different diseases, and the y-axis shows number of farms that have suffered the mentioned diseases. Each bar is also shown with a percentage of infected farms for each disease. Nearly half of the shrimp farmers (49%) have experienced disease outbreaks. There was significant presence of the Red Body Disease (19.2%), occurring in about 13% of the surveyed area from 30 to 40 days post-stocking. This disease was mainly caused by the TSV and WSSV. Clinical manifestations include red or pink bodies, as well as the shrimp swimming along the shore or floating to the surface. Hepatic Disease, caused by unknown pathogens, was the second most common disease, reported by 17.3% of farmers. The main external expression was small, but internal analysis would show black or yellow livers. The diseases of Slow Growth Syndrome, Intestinal Disease, Early Mortality Syndrome (EMS), and White Feces Disease were reported by between 1.92% and 7.69% of farmers, and other disease outbreaks were reported by 3.8%.

Farmers in the non-GAP applied systems had serious problems with disease outbreak, as 64% of respondents reported outbreaks over 65% of the covered area. Intestinal Disease, White Spot Disease, and Hepatic Disease were most prominently reported, at 25%, 21%, and 16% of farms, respectively. Typical diagnosis of White Spot Syndrome is with white spots appearing over the cephalothorax and abdominal exoskeleton, shrimp swimming along pond shore or floating on the water surface, and mass casualty within a few days. The other diseases, such as Red Body, EMS, White Feces Diseases, Slow Growth Syndrome, and others, were reported by 32% of respondents. The farmers diagnosed these diseases based on clinical examinations. Farmers were unable to identify certain causes of diseases because they had limitations and little experience in diagnosing and distinguishing different diseases.

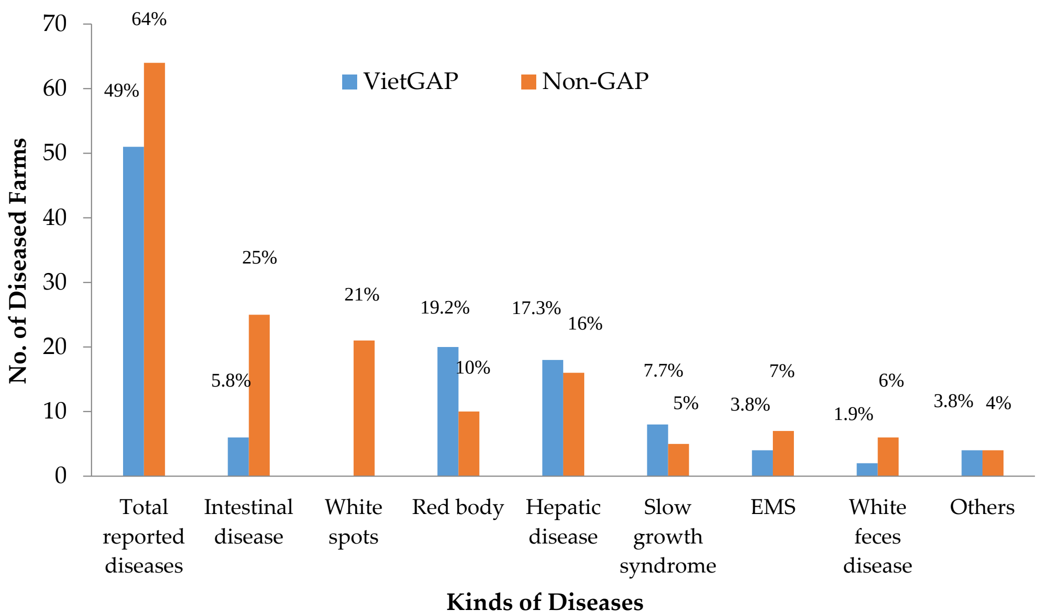

Figure 5. Diseases affecting farms reported by farmers during the last production cycle (Source: Author's survey, 2019).

3.3.2. Situation of Economic Losses and Food Safety Reported by Farmers

Diseases directly impact the harvest yield. The result indicate, as shown in Table 4, that the farmers in the VietGAP applied system experienced lowered productivity, resulting in financial loss at around 50% of the profit for farmers. If the disease outbreak happened within one month post-stocking, the mass mortality would lead to a lack of harvest. Such situations led to 17.3% of farmers falling into debt at around 2914 USD/ha due to loss of investment cost. Virus-caused diseases like Red Body, White Spots, and EMS were the main reasons for economic loss. All intensive shrimp farms usually apply the full harvest method by using dragging nets to empty the entire pond. Finding/contacting buyers was done a couple of days before the intended harvest. The purchasing process was done at the farm gate, and the buyers were responsible for shipment and distribution of products to the processing companies. Therefore, farmers' responsibility for the quality of the product ends when it is sold, immediately after harvest. In the non-GAP applied system, the diseases obviously caused profit loss for farmers, and the amount of loss was estimated at 8970 USD/ha. The profit loss was correlated with the 47.4% decrease of harvest yield (12.6 compared to 5.95 MT/ha). The infection also increased chemical and drug costs to around 5468 USD/ha/crop in comparison to 3860 USD/ha/crop, therefore reducing net profit; 24% of farmers had a negative profit. In the MD, attempts to eradicate diseases in intensive shrimp farming have failed so far. White Spot Disease was the substantial cause of the major farming disasters in Vietnam, other than diseases caused by viruses.

According to the survey, approximately 56% of shrimp materials of the VietGAP applied system were sold to small traders/collectors. Small traders are unable to purchase shrimp products in larger volumes (more than one MT/transaction) because of limitations with infrastructure. Following the VietGAP standard, farmers could sell directly to the processing companies or trader networks of the companies when they could ensure the quality and safety (29% of shrimp materials). The others could sell to wholesale buyers when high yields were harvested each time. In the Soc Trang province, 81% of shrimp were exported, and only 19% were consumed domestically. Because commercial shrimp farming in Vietnam is oriented towards exports, buyers had high requirements for food safety. Fishery product imports from Vietnam are rejected for various reasons depending on markets. For example, in the EU market, veterinary drug residue, bacterial contamination, and heavy metals are the major problem. In the US market, bacterial contamination, hygienic condition, and labeling are the main reasons for rejection. Veterinary drug residue and bacterial contamination seem to be the major problems for entering the Japanese market [10,19]. This may reflect that various contaminations (veterinary drugs, pesticide residues, and bacterial or other contaminants) in production are not well controlled or tested. This means that there had to be a guarantee that the product was free of any veterinary drugs, specifically antibiotic residue. The guarantees are usually obtained by taking samples from each batch to a lab for testing. This is done by the buyers and the company's own staff, and is required from certain markets before export. In order to evaluate the impact of farming practices of control points on the quality of products, the author made a calculation of over 104 respondents. The result showed that there were 770 transactions being done within three years, of which 384 transactions were subject to the requirements of food safety checks for export (commercial size of 100 individuals/kg and at least one MT per transaction), and, eventually, only six violations of transactions were recorded. The reasons for rejection at the processing and export companies' gates were bacterial contamination (four transactions) and other contaminants (two transactions). Farmers have tried to produce safe products for export, as they are hopefully acquiring an additional price premium of 0.14 USD/kg, plus an average selling price of 4.82 USD/kg for the average size of 79 individuals/kg. The farmers assessed themselves as having a high capacity to meet requirements (80%), as they have acquired some experience with VietGAP.

Table 4. Economic losses by diseases and food safety in the VietGAP and non-GAP systems.

Categories	Unit	VietGAP	Non-GAP
		Sample = 104	Sample = 100
		Value (and Stdev.)	Value (and Stdev.)
Productivity of healthy crop/ha	MT	5.51 ± 2.57	12.6 ± 5.19
Productivity of diseased crop/ha	MT	2.67 ± 1.18	5.95 ± 2.07
Average profit in healthy crop/ha	USD	14,084 ± 5420	28,272 ± 12,046
Average profit in diseased crop/ha	USD	7787 ± 1152	8961 ± 3312
Average size	Individuals/kg	79 ± 12	70.8 ± 42
Average selling price	USD/kg	4.82 ± 0.98	4.70 ± 2.02
No. of shrimp transactions [1] within the last three years	Transactions	770 *	726 *
No. of transactions being quality tested within the last three years	Transactions	328 *	66 *
No. of transactions being rejected within the last three years	Transactions	6 *	12 *
Average price premium [2] for passing on test	USD/kg	0.14 ± 0.08	0.23 ± 0.6

[1] Transaction means the number of times selling shrimp to buyers. [2] Price premiums: Value plus average selling price. * The numbers were calculated as a sum of surveyed samples. (Source: Author's survey, 2019).

Shrimp farming in the non-GAP system is dominated by small-scale producers with an average harvest yield per cycle of less than one MT per farm. Therefore, small traders/collectors purchased 68% of shrimp products. They reside in communes to collect and mix shrimp from tens of kilograms in containers for shipping to processing companies. Only some farms (2%) with high harvest yield could sell shrimp directly to processing companies. This indirect purchasing system made it difficult to ensure traceability from the point of the initial production stage. Considerably, 38% of shrimp products were sold from collectors or wholesalers to supermarkets, local markets, and seafood restaurants for domestic consumption. Domestic consumption requires shrimp products to be still alive and fresh when they reach the table. The buyers in this case preferred bright colors and nice appearance rather than safety factors, such as residue traces. Farmers in the non-GAP system use chemicals/antibiotics more freely. Traders knew the situation clearly, so they did not prioritize safety when making transactions. The total of 726 shrimp product transactions were carried out by 100 households within the last three years; the percentage that had their quality tested in the lab was insignificant (66/726, equal to 9%). In fact, farmers used a variety of chemical compounds, including antibiotics in disease prevention and treatment, and these caused 10 rejected transactions due to antibiotic contamination and two rejected transactions for violation of color requirements (not a satisfactory dark orange color after boiling). However, farmers had a strong motivation to produce safe products because of the high price premium at 0.23 USD/kg once shrimp pass the safety test.

3.4. Remarks from the Two Systems

There has been a remarkable increase in shrimp farming in the MD over the last decade. This development has led to problems of disease outbreak, and then to loss of quality of the shrimp products exported for global consumption. The farmers made significant attempts to deal with the issue by introducing the quality certification of VietGAP. However, to answer the question of whether VietGAP farmers have better practices than non-GAP farmers in quality management, a comparison box is synthesized in Table 5. As can be seen from the table, there is a minor gap between what farmers actually do and the principles in the VietGAP applied system; there are also better practices than those in the non-GAP applied system. The critical control points include higher ratios of reservoir construction for water quality monitoring (92% of respondents vs. 25.5% of respondents, respectively), lower stocking management (39 PL/m^2 for VietGAP system vs. 93 PL/m^2 for non-GAP system), non-use of banned chemical compounds for 30.5% of respondents, and diary records under the guidance of the VietGAP program (100% of respondents). However, it was noticed that some control points were not actually complied with fully according to the recommended principles of VietGAP applied farmers. Bottom sludge was occasionally disposed of incorrectly and infrequently, and there was usage of untested PL. The key reason was the lack of financial capital available from farmers. In some cases, the farmers did not understand the underlying rationale of these control points, and, therefore, they did not feel intrinsically motivated to comply with them. Low disease report rate and illegal discharge were problems, although the principles of VietGAP require applicants to instantaneously report the disease situation in order to avoid horizontal transmission to adjacent ponds. In contrast, farmers in the non-GAP applied system occasionally practiced freely, favoring personal economic interests, such as high stocking density, few tested PL, antibiotic usage, water monitoring by only visual aids, and, occasionally, overfeeding. These practices finally affected the disease control and quality management of the two systems. This was reflected in that fewer farmers in the VietGAP system (49%) experienced disease than non-GAP farmers (64%). Practicing VietGAP has increased the ratio of shrimp transactions that are eligible for safety testing at the processing gate for export, while reducing the rejection ratio due to contamination violations. The ratio of GAP products sold to processing companies for export was relatively high, which created as short a time as possible so the product would not spoil, as their shrimp products do not go through long distances or multiple agents.

Table 5. Comparison of disease and quality control practices and their results in the two systems.

Control Points	VietGAP Applied System (Sample = 104)	Non-GAP Applied System (Sample = 100)
Farm construction	Having required reservoirs: 92% Have a good shed: 100%	No reservoirs or reservoirs with very small area: 25.5% Temporary sheds: 100%
Pond design and preparation/renovation	No siphon pit, no bottom plastic lining, and not using surrounding net Sludge removal once/year: 52.5% Breaking time guarantee: 96% Short bottom dry	Siphon pit: 85%; plastic lining; 15%; Using surrounding net: 100% Sludge removal once/year: 100% Breaking time guarantee: 55% Short bottom dry
Stocking management	Virus-free PL: 89.7% through cooperative contracts Low Density (39 PL/m^2) Size: PL12	Virus-free PL: 77.8% from central region High Density (93 PL/m^2), 20% above recommendation Size: PL11

Table 5. *Cont.*

Control Points	VietGAP Applied System (Sample = 104)	Non-GAP Applied System (Sample = 100)
Feeding	Purchasing from companies/the 1st agent: 57.3% Storage period: 9 days Manual feeding: 100% Low feed conversion ratio (FCR): 1.11 Overfeeding reported: None Keeping diary officially: 100%	Purchasing from the 2nd agent: 81.6% Storage period: 5 days Manual feeding: 80%, machine feeding: 20% High FCR: 1.20 Overfeeding reported: 14% Less book recording (for material use accounting)
Water monitoring	Using toolkit: 84% Compensation of in-pond water: 74% Bad phytoplankton blooming: None	Sensory monitoring: 70%, unfrequently Bad phytoplankton blooming: 30%
Chemical use	Non-use of antibiotics Complied fully with VietGAP program	Use of anti-biotics: 30.5% Stopping 13 days prior to harvest
Waste treatment	Release waste water directly: 21% Dispose of sludge correctly: 50% Occasional illegal discharge	Release waste water directly: 22% Dispose of bottom sludge correctly: 81% No illegal discharge
Disease treatment	Chemical use: 30% Less reporting of disease	Chemical use: 57.5% Less reporting of disease
Result of the Systems	**VietGAP applied system (Sample = 104)**	**Non-GAP applied system (Sample = 100)**
Disease reported	49%	64%
Quality and Food Safety: Tested transactions Rejected transactions	328/770 = 42.6% 3/164 = 1.83%	66/726 = 9% 12/66 = 18.2%

Note: The unit % represents for the percentage of respondents. (Source: Author's survey, 2019).

4. Discussion

It is critical that the VietGAP-certified products truly are safe, of good quality, and contribute to sustainable agriculture [19,22]. Throughout the research, the VietGAP standard has gained significant achievements in reducing disease, with VietGAP applied farmers reported fewer diseases compared to non-GAP applied farmers. In terms of quality management, the VietGAP applied system allows farmers to produce quality products to fulfill the requirements of global customers. The ratio of shrimp shipments eligible for safety tests has gone up, while the rejection ratio that was due to contamination violations has declined (Table 5).

Regarding economic efficiencies, VietGAP applied farmers are provided insurance against loss due to disease outbreaks (half-lost income compared to two-thirds). VietGAP shrimp products were bought at a slightly higher price in comparison to non-GAP products. This price premium does not come from VietGAP certification itself, but from passing the safety test. Actually, the financial value that comes with the certification may be the reputational benefit [19,20]. However, VietGAP is not recognized in the international markets yet; the buyers cannot sign any contract for price premiums when exporting, as the international customers are not willing to pay more for VietGAP products. Generally speaking, VietGAP has significant meaning in quality management and disease control, but it is not a financial benefit itself, and it is costly for farmers to acquire certification. Findings from Graffham et al. [31] indicated that the three most significant withdrawals of certifications were related to high costs without high returns. Actually, the purpose of the VietGAP is not to increase the quality or provide financial security, but to improve production practices of farmers for safer and more sustainable agriculture. The application of VietGAP is according to a gradual schedule to benchmark international certification schemes, such as those of the GlobalGAP and Aquaculture Stewardship Council (ASC), to be unified under the regulations of Vietnam [21,22]. Therefore, VietGAP is not a target for the shrimp industry because it is not recognized internationally and it does not show any proof of safety. However, the application of the VietGAP standard is still necessary because it sets a milestone prior to benchmarking international certifications of the ASC or GlobalGAP [22,31].

5. Conclusions

It is impossible to evaluate the quality of shrimp products from a limited study of the production, as the hazards affecting quality could come from the whole supply chain. However, this study has tried to indicate what farming practices should be improved for better quality management at the farm site. Alas, some important factors are proven with the comparison between VietGAP farming practices and non-GAP farming practices. This study shows that farmers following the VietGAP system could gain better control of diseases and quality than those of the non-GAP applied system. This is shown through multiple categories of control points, e.g., construction of reservoirs, low density, use of toolkits, and less use of chemicals and antibiotics. It should be noted that farmers in the VietGAP system have to monitor the farms more closely to keep up with the correct regulations and parameters. This includes, for example, the frequency and treatment of bottom sludge or disease and illegal discharge and reporting these to the management. The efficiency of VietGAP certification in quality management is expressed in that fewer farmers in this system reported diseases and minor economic damage than those in the non-GAP applied system. Shrimp produced according to the VietGAP standard could fulfill quality indicators demanded by importers with fewer transactions being rejected. Therefore, the meaning of VietGAP in quality management is significant. Considering economic terms, the role of VietGAP is not to generate high profit, but rather to reduce risk caused by disease outbreaks and antibiotic contamination rejections. This finding may unravel the confusion in the literature review about the question of whether VietGAP should be encouraged even at a low price premium.

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