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The Use of Drugs, Chemicals, Herbs, and Herbal Extract Products in Grow-out Farms of Snakehead (*Channa striata*) and Pangasius Catfish (*Pangasianodon hypophthalmus*) in the Mekong Delta, Vietnam

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Abstract

This study aimed to investigate the current use of drugs, chemicals, herbs, and herbal extract products in grow-out farms of snakehead (*Channa striata*) and Pangasius catfish (*Pangasianodon hypophthalmus*) in the Mekong Delta, Vietnam. The survey was conducted with a total of 60 Pangasius catfish grow-out farms in An Giang and Dong Thap provinces, and 60 snakehead grow-out farms in An Giang and Tra Vinh provinces. The results showed that bacterial diseases were commonly reported by snakehead farmers (1-4 episodes per crop) and Pangasius catfish farmers (1 to 12 episodes per crop). Farmers used 12 types of single antibiotics and a mixture of two antibiotics in Pangasius catfish, and eight types of antibiotics in snakehead aquaculture. However, Pangasius catfish and snakehead farmers used enrofloxacin and ciprofloxacin, which are banned antibiotics according to the Vietnamese authority regulations. For the use of herbs and herbal extract products, a variety of commercial products were used by farmers which claimed different purposes for use. According to the farmers, the quality and effectiveness of these products were questionable. Some farmers used traditional herbs following their experiences using traditional medicines for humans and did not really know about the application doses. Thus, it would be requested for in-depth studies on the use of herbs as on-farm treatments, which would provide evidence for the use of herbs in the industry.

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Keywords

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Introduction

In recent decades, Pangasius catfish (*Pangasianodon hypophthalmus*) has become one of the dominant species that is farmed intensively in the Mekong Delta and has become the major exporting product in the global seafood market. The production of Tra catfish has risen rapidly from 93 thousand tons in 2000 to 1.12 million tons in 2020 (Directorate of Fisheries, 2020). Snakehead *(Channa striata)* is one of the common domestically consumed fish with a production of 40,000 tons year^{-1} (Tran Hoang Tuan *et al.*, 2014). Snakehead is cultured mainly in ponds, cages, and lined tanks in Dong Thap, Vinh Long, Tra Vinh, and An Giang provinces (Huynh Van Hien *et al.*, 2011). However, with these intensive culture practices, frequent disease occurrences have been reported, including bacillary necrosis of Pangasius (BNP), caused by *Edwardsiella ictaluri*, and motile *Aeromonas* septicaemia (MAS) in Pangasius catfish (Phan *et al.*, 2009; Phu *et al.*, 2016) and bacterial diseases and parasite infections in snakehead (Pham Minh Duc *et al.*, 2012; Nguyen Quoc Thinh *et al.*, 2020).

The increase in bacterial diseases and other pathogens causing high mortality has negatively impacted fish production and profits. The use of chemicals and other compounds to control water quality, improve digestibility, and treat diseases have been popular in aquaculture (Nguyen Quoc Thinh *et al.*, 2014; Phu *et al.*, 2016; Ström *et al*., 2019; Nguyen Quoc Thinh *et al.*, 2020). Twenty-four types of antimicrobials were used to control bacterial disease in Pangasius catfish, as reported in a survey done in 2011 (Phu *et al.*, 2016), and five additional types in 2019 (Ström *et al*., 2019). Also, other chemicals used as disinfects, herbs, and probiotics are also used in Pangasius catfish farming. For snakehead farming, seven types of antibiotics and eight types of compounds for disinfecting and controlling parasites were used to control diseases during culture periods (Nguyen Quoc Thinh *et al.*, 2020). Information on the use of herbs in aquaculture is limited.

The use of herbs or herbal products has not been widely studied at the farm level. Garlic is used to control bacterial diseases in aquaculture due to its antimicrobial properties (Kim Van Van, 2012). Adding *Yucca schidigera* extract has been shown to enhance shrimp growth and survival rates (Nguyen Phu Hoa, 2012). Other researchers have explored the antimicrobial and antioxidant properties of herbal extracts, potentially for applications in aquaculture (Bussmann *et al.*, 2010; Tekwu *et al.*, 2012; Ocheng *et al.*, 2014). However, information on the use of herbs in Pangasius catfish (*Pangasianodon hypophthamus*) and snakehead *(Channa striata)* aquaculture has not been clearly illustrated. The aims of this study were to investigate the use of chemicals common in aquaculture with a focus on the application of herbal products and to provide background information for further in-depth studies.

Methodology

The study was conducted from January to April 2017 by interviewing 60 Pangasius catfish farmers in Dong Thap and An Giang provinces and 60 snakehead farmers in An Giang and Dong Thap provinces, Vietnam. A total of 120 farmers were interviewed face to face. The interviewed farms were randomly selected from the list provided by provincial agriculture and rural development offices. The semi-structured questionnaire was piloted in two households in each group and included technical information (grow-out pond, input pond, stocking density, year of farming, production, feed conversion ratio, and training), disease occurrence (types of disease and chemicals used), and information on the use of herbal products (types of herbal products, dosages, and modes of application). Results were expressed in descriptive statistics, namely frequency of occurrence, mean value, and standard deviation, using Microsoft Excel 2010.

Results

General information about the catfish and snakehead farms

The Pangasius catfish farmers had more experience in fish farming compared to the snakehead farmers (**Table 1**). This is because catfish aquaculture began intensive farming in 2000 (De Silva & Phuong, 2011), whereas snakehead aquaculture has been expanding for less than ten years (Huynh Van Hien *et al.*, 2011; Tran Hoang Tuan *et al.*, 2014). Pangasius catfish fingerlings were obtained from the local places in Dong Thap and An Giang provinces, which had numerous catfish nurseries, while snakehead fingerlings were transported mainly by truck to Dong Thap province from grow-out farms in Tra Vinh, 60 to 100km down-stream.

Although both types of farms had similar stocking densities, the productivity of Pangasius catfish was much higher than the snakehead. This is because the total production of Pangasius catfish was much higher than the total production of snakehead (Tran Hoang Tuan *et al.*, 2014; Directorate of Fisheries, 2020). Checking for antibiotics before harvesting and trading was a common practice in Pangasius catfish aquaculture compared to the much lower rate in snakehead aquaculture, which can be explained by the fact that snakehead is only traded to middle-men and sold for domestic consumption at local markets, whereas Pangasius catfish is mainly exported. It should be highlighted for attention that the fish produced for local markets followed similar aquaculture patterns as other fish produced for local consumption, *e.g.* red tilapia (Tran Minh Phu *et al.*, 2017).

Disease symptoms reported by Pangasius catfish and snakehead farmers

Most farmers reported that bacillary necrosis of Pangasius and motile *Aeromonas* septicaemia were the two most common bacterial diseases in Pangasius catfish (**Table 2**). This means that the two main diseases had not been controlled in previous years. The diseases also appeared often during the flooding season with the frequency of 1 to 12 episodes per crop. Thus, catfish bacterial disease control should be taken into account for better fish production. Farmers had to use antimicrobial compounds to treat the diseases, although prevention methods were applied such as feeding the fish immunostimulant products and feed additive products. Pale gill and liver syndrome and parasite infection also occurred frequently, similar to the previous report of Phu *et al.* (2016). Yellow fillet syndrome in Pangasius catfish seemed to occur more frequently compared to previous findings in 2011, in which less than 5% of farmers reported it. Thus, fish health management practices in Pangasius catfish farming need to have the involvement of different stakeholders who can contribute to the sustainable development of the industry.

Motile *Aeromonas* septicaemia, body hemorrhages, parasite infection, and liver syndrome were the most common diseases and symptoms reported by snakehead farmers (**Table 2**). However, the disease occurrences were less

Table 1. General information about the catfish and snakehead farms

	Pangasius catfish (n = 60)	Snakehead (n = 60)
Years of farming (years)	10.6 ± 6.4	5.8 ± 3.5
Training (%)	75	60
Area of grow-out pond (m^2)	5767 ± 3430	881 ± 354
Stocking density (fish/m^2)	56 ± 24	56 ± 20
Feed Conversion Ratio	1.6 ± 0.2	1.28 ± 0.2
Harvest size (g/fish)	974 ± 338	811 ± 212
Checking antibiotic before selling (%)	86.7	3.3
Productivity (tons/ha/crop)	422 ± 162	152 ± 78

Table 2. Diseases symptoms reported by catfish and snakehead farmers (%)

Reported disease symptoms	Pangasius catfish (n = 60)	Snakehead (n = 60)
Bacillary necrosis of Pangasius (BNP)	91.7	-
Motile *Aeromonas* septicaemia (MAS)	90	66.3
Pale gill and liver syndrome	60	-
Parasite infection	43.3	60
Yellow fillet syndrome	30	-
Liver syndrome	-	60
Fungi infection	-	11.7
Body hemorrhages	-	56.7
Abnormalities	-	78.3

Note: "-": no report.

frequent than in the Pangasius catfish, with 1 to 4 episodes per crop. The bacterial diseases in snakehead were caused by infections of *Aeromonas* spp., *Edwardsiella* sp., *Streptococcus* spp., and *Pseudomonas* spp., while the parasite infections included *Gyrodactylus*, *Spinitectus*, *Pallisentis*, and protozoae (*Trichodina*, *Apiosoma*, *Henneguya*, and *Chilodonella*) (Pham Minh Duc *et al.*, 2012). The findings were consistent with those of Nguyen Quoc Thinh *et al.* (2020), who reported similar disease symptoms in snakehead but more cases in liver symptoms were reported (80%). For Pangasius catfish, farmers applied antimicrobials to control the motile *Aeromonas* septicaemia, body hemorrhages, and liver syndrome, while the parasites were controlled by different chemicals.

Antibiotic use by catfish and snakehead farmers

The number of antibiotics used in Pangasius catfish included 12 types of single antibiotics and a mixture of two antibiotics, fewer than reported in 2011 (Phu *et al.*, 2016) (**Table 3**). Compared to a recent survey done by Ström *et al.* (2019), five types of antibiotics were used by catfish farmers including enrofloxacin. The more types of antibiotics used by farmers in this study can be explained by the higher number of interviews (120, whereas in the survey of Ström *et al.* (2019), only 13 farmers were interviewed in An Giang province). Antibiotic use in snakehead was similar to the survey of Nguyen Quoc Thinh *et al.* (2020), in which eight types of antibiotics were used. However, enrofloxacin and ciprofloxacin, banned antibiotics according to the Ministry of Agriculture and Development (MARD), were used by both Pangasius catfish and snakehead farmers (MARD, 2016). The sources of these antibiotics were unknown according to the farmers who obtained them from a chemical company. According to Mai Van Tai (2012), 28 antibiotics can be used in aquaculture in Vietnam, while in the USA, only four types of antibiotics have been approved for use in aquaculture. The farmers reported that the use of antibiotics was mainly based on their experiences, and not on scientific testing of the antimicrobial compounds. Thus, it is urgent to optimize the use of antibiotics or develop better regulations.

Chemicals, probiotics, and nutritional products

Many types of chemicals were used to disinfect water, control ectoparasites, and to improve water quality (**Table 4**). Iodine and BKC were widely used to disinfect water in both catfish and snakehead ponds, whereas copper sulfate and chlorine were used periodically to control the ectoparasites in Pangasius catfish twice a month. These practices were similar to previous findings, meaning that the ways to

Table 3. Antibiotics reportedly used by Pangasius catfish and snakehead farmers (%)

Groups	Antibiotic	Pangasius catfish (n = 60)	Snakehead (n = 60)
Betalactam	Amoxicillin	40	36.7
	Ampicillin	1.7	3.3
	Cephalexin	13.3	1.7
	Cefotaxime	3.3	-
Polymyxin	Colistin	10	-
Quinolone	Ciprofloxacin	8.3	6.7
	Enrofloxacin	28.3	45
	Levofloxacin	16.7	1.7
Aminoglycoside	Gentamicin	11.7	-
Tetracycline	Doxycycline	35	25
	Oxytetracycline	20	10
Phenicol	Florfenicol	36.7	38.3
Mixture	Sulfonamide+ trimethoprim	28.3	8.3

Note: "-": no report.

Table 4. The use of chemicals, probiotics, and nutritional supply products reported by Pangasius catfish and snakehead farmers (%)

	Pangasius catfish (n = 60)	Snakehead (n = 60)
Disinfectant, ectoparasite control, and water quality improvement		
Iodine	53.3	60
Copper sulfate	30	16.7
BKC	41.7	31.7
$KMnO_4$	30	8.3
Lime	73.3	45
Chlorine powder	53.3	10
Glutaraldehyde	8.3	-
Salt	70	23.3
Internal parasite control		
Praziquantel	23.3	70
Ivermectin	41.7	-
Mixture of minerals and vitamins	78.3	95
Probiotics	63.3	93.3

Note: "-": no report

control parasites and water quality have not been improved in recent years, and only chemicals and water exchange for disinfection are used (Phu *et al.*, 2016; Nguyen Quoc Thinh *et al.*, 2020). Praziquantel was used in both species while ivermectin was only used for catfish because it is toxic to snakehead. Most of the farmers used probiotics and feed additive products containing vitamins and minerals, although the effectiveness was not assured, as reported by the farmers.

Herbs and herbal extract products

Herbs and herbal extract products were commonly used by Pangasius catfish farmers,

45% of the farmers used commercial products and 8.3% of farmers used natural herbal products (**Table 5**). Snakehead farmers also used natural herbal products (16.7%) and commercial products (8.3%). Natural herbs like *Cleome chelidonii*, *Combretum daystachyum*, and garlic were commonly used to enhance liver function, control ectoparasites, and treat bacterial diseases. The natural herbs were normally dried and boiled in water before being applied into ponds or mixed into feed. Some herbs were ground and used fresh, such as garlic, *Areca catechu*, and curcumin. Nine types of herbal extract products produced by commercial companies were popularly used by Pangasius catfish farmers, whereas only three types were used by snakehead farmers. These products were advertised as enhancing liver function, controlling ectoparasites and bacterial diseases, and improving water quality, according to the labels. However, the effectiveness of the products was unknown as traditional herbal medicines were used empirically by farmers. In addition, the quality of the herbal extract products has not been validated due to different types of compounds in the products.

Herbal extracts have been reported to contain alkaloids, terpenoids, tannins, saponins, glycosides, flavonoids, phenolics, steroids, or essential oils (Citarasu, 2010; Chakraborty & Hancz, 2011) which can reduce stress, improve growth, and supply essential compounds. Nguyen *et al.* (2020) reported that *Phyllanthus amarus* extract had a high antioxidant property *in vitro*, followed by *Piper betle*, *Psidium guajava*, *Euphorbia hirta*, and *Mimosa pudica*. For antimicrobial activities, *P. amarus* extract also showed the highest activity against two different strains of *Aeromonas hydrophila*. Nhu *et al.* (2019) revealed that plant extract-based diets modulated immune responses and resistance to bacterial infection differently in Pangasius catfish (*Pangasianodon hypophthalmus*). *Perilla frutescens* was shown to have the highest antifungal activity against snakehead pathogenic fungi among five herbal extracts examined and collected in the Mekong Delta (Dang Thuy Mai Thy *et al.*, 2020). Earlier studies have presented

Table 5. The use of herbs and herbal extract products and their functions reported by Pangasius catfish and snakehead farmers (%)

Items and description	Pangasius catfish (n = 60)		Snakehead (n = 60)	
	Herbs	Herbal extract products	Herbs	Herbal extract products
To enhance liver function				
+ *Eclipta alba* (Cỏ mực)	-	1.7	5	-
+ *Phyllanthus urinaria* (Diệp hạ châu)	-	1.7	5	-
+ Artichoke (*Cynara cardunculus* var. *Scolymus*), Amalaki (*Phyllanthus emblica*), and Arjuna (*Terminalia arjuna*)	-	3.3	-	1.7
+ *Cleome chelidonii* (Cây mần ri)	3.3	1.7	-	-
+ Artichoke (*Cynara cardunculus* var. *Scolymus*)	-	1.7	-	-
To control ectoparasites				
+ *Combretum daystachyum* (Trâm bầu)	1.7	10	-	6.7
+ *Areca catechu* (Cau)	-	-	8.3	-
+ Curcumin (Nghệ)	-	-	1.7	-
To control bacterial diseases				
+ Garlic (tỏi)	6.7	8.3	-	-
+ Alkaloid, flavones, gallic acid, terpenoid, and neolignan	-	1.7	-	-
To improve water quality				
Yucca schidigera extract	-	63.3	-	45

Note: "-": no report

that skin mucosal immune responses could be promoted in rohu (*Labeo rohita*), Caspian roach (*Rutilus rutilus*), and common carp (*Cyprinus carpio*) when the fish were fed diets in which the extracts of ginger (*Zingiber officinale Roscoe*) (Sukumaran *et al.,* 2016), garlic (*Allium sativum*) (Ghehdarijani *et al.,* 2016), and date palm fruit (*Phoenix dactylifera* L.) (Hoseinifar *et al.,* 2015) had been incorporated, respectively. Many scientific publications have documented that the crude ethanol extract of *Psidium guajava* has effective properties to enhance the immune responses and defense mechanisms in Pangasius catfish (Nhu *et al.,* 2019; 2020), rohu (Giri *et al.,* 2015; Fawole *et al.,* 2016), and tilapia (Gobi *et al.,* 2016).

In this study, farmers reported using a variety of commercial products without verification of quality and relied on the types of available bioactive compounds that were popular in the market. Farmers did not know about the quality and were unsure about their effectiveness during application. Some farmers used traditional herbs following their experiences using traditional medicines for humans and did not really know about the proper application doses. Thus, it would be recommended for in-depth studies on the efficacy of herbs used as on-farm treatments, which can then be applied widely in the industry. The use of herbal extracts could reduce the costs of treatments and be more environmentally friendly treatments as they tend to be more biodegradable than synthetic molecules and less likely to produce drug resistance in parasites due to the high diversity of plant extract molecules (Blumenthal *et al.,* 2000; Logambal *et al.,* 2000).

Conclusions

The survey revealed that BNP and MAS are still major pathogens that Pangasius catfish farmers have to deal with as part of fish health management. Bacterial diseases in snakehead were the primary issue, with 1 to 4 episodes per crop. Farmers of both fish used antibiotics to control bacterial diseases. Twelve types of single antibiotics and a mixture of two antibiotics were used in Pangasius catfish and eight types of antibiotics were used in snakehead aquaculture. However, enrofloxacin and ciprofloxacin, banned antibiotics according to MARD, were used by both Pangasius catfish and snakehead farmers. For the use of herbs and herbal extract products, farmers used the varieties of commercial products that were available for farmers which claimed different purposes for use. According to the farmers, the quality and effectiveness of these products were questionable. Some farmers used traditional herbs like *Eclipta alba*, *Phyllanthus urinaria*, *Cleome chelidonii*, *Areca catechu*, and garlic, among others, following their experiences using traditional medicines for humans, and they did not really know about the application doses. Thus, it would be recommended for further studies on the efficacy of herbs used as on-farm treatments, which can then be widely applied in the industry.

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References

Blumenthal M., Goldberg A., & Brinckmann J. (2000). Herbal medicine: Expanded commission E monographs: Integrative Medicine Communications.

Bussmann R. W., Malca-García G., Glenn A., Sharon D., Chait G., Díaz D., Pourmand K., Jonat B., Somogy S., & Guardado G. (2010). Minimum inhibitory concentrations of medicinal plants used in Northern Peru as antibacterial remedies. Journal of Ethnopharmacology. 132(1): 101-108. DOI: 10.1016/j.jep.2010.07.048.

Chakraborty S. B. & Hancz C. (2011). Application of phytochemicals as immunostimulant, antipathogenic and antistress agents in finfish culture. Reviews in Aquaculture. 3(3): 103-119.

Citarasu T. (2010). Herbal biomedicines: a new opportunity for aquaculture industry. Aquaculture International. 18(3): 403-414. DOI: 10.1111/j.1753-5131.2011.01048.x.

Dang Thuy Mai Thy, Bui Thi Bich Hang & Tran Thi Tuyet Hoa (2020). Antifungal activity of extracted herbs on snakehead pathogenic fungal. Can Tho University Journal of Science. 56(1): 129-136. DOI: 10.22144/ctu.jsi.2020.015 (in Vietnamese).

De Silva S. S., & Phuong N. T. (2011). Striped catfish farming in the Mekong Delta, Vietnam: a tumultuous path to a global success. Reviews in Aquaculture, . 3(2): 45-73. DOI: 10.1111/j.1753-5131.2011.01046.x.

Directorate of Fisheries (2020). Reduction of striped catfish export in 2019. Retrieved on September 22, 2020 from https://tongcucthuysan.gov.vn/vi-vn/th%C6%B0%C6%A1ng-m%E1%BA%A1i-th%E1%BB%A7y-s%E1%BA%A3n/xu%E1%BA%A5t-nh%E1%BA%ADp-kh%E1%BA%A9u/doc-tin/013997/2019-12-05/du-bao-kim-ngach-xuat-khau-ca-tra-nam-2019-giam-manh on September 22, 2020.

Fawole F. J., Sahu N. P., Pal A. K., & Ravindran A. (2016). Haemato-immunological response of *Labeo rohita* (Hamilton) fingerlings fed leaf extracts and challenged by *Aeromonas hydrophila*. Aquaculture Research., 47(12): 3788-3799. DOI: 10.1111/are.12829.

Ghehdarijani M. S., Hajimoradloo A., Ghorbani R., & Roohi Z. (2016). The effects of garlic-supplemented diets on skin mucosal immune responses, stress resistance and growth performance of the Caspian roach (*Rutilus rutilus*) fry. Fish and Shellfish Immunology., 49: 79-83. DOI: 10.1016/j.fsi.2015.12.021.

Giri S. S., Sen S. S., Chi C., Kim H. J., Yun S., Park S. C. & Sukumaran V. (2015). Effect of guava leaves on the growth performance and cytokine gene expression of *Labeo rohita* and its susceptibility to *Aeromonas hydrophila* infection. Fish and Shellfish Immunology. 46(2): 217-224. DOI: 10.1016/j.fsi.2015.05.051.

Gobi N., Ramya C., Vaseeharan B., Malaikozhundan B., Vijayakumar S., Murugan K. & Benelli G. (2016). *Oreochromis mossambicus* diet supplementation with *Psidium guajava* leaf extracts enhance growth, immune, antioxidant response and resistance to *Aeromonas hydrophila*. Fish and Shellfish Immunology. 58: 572-583. DOI: 10.1016/j.fsi.2016.09.062.

Hoseinifar S. H., Khalili M., Rufchaei R., Raeisi M., Attar M., Cordero H., & Esteban M. Á. (2015). Effects of date palm fruit extracts on skin mucosal immunity, immune related genes expression and growth performance of common carp (*Cyprinus carpio*) fry. Fish and Shellfish Immunology. 47(2): 706-711. DOI: 10.1016/j.fsi.2015.09.046.

Huynh Van Hien, Nguyen Hoang Huy & Nguyen Thi Minh Thuy (2011). Technical and economical comparison of snakehead (*Channa striata*) pond culture by trashfish and commercial pelled feed in An Giang and Dong Thap provinces, Vietnam. Proceedings of Vietnam National Aquaculture Conference. Nong Lam University: 480-487.

Kim Van Van (2012). The use of garlic in treatment of bacterial disease. In: Phu T. Q. (Eds.). Principals and technique in aquaculture. Agriculture Publisher, HCMC. 170 pages.

Logambal S., Venkatalakshmi S. & Michael R. D. (2000). Immunostimulatory effect of leaf extract of *Ocimum sanctum* Linn. in *Oreochromis mossambicus* (Peters). Hydrobiologia, 430(1-3): 113-120. DOI: 10.1023/A:1004029332114.

Mai Van Tai (2012). Use of veterinary medicines in Vietnamese aquaculture: current status. FAO Fisheries and Aquaculture Technical Paper. (547): 91-98.

MARD (2016). Circular No. 10/2016/TTBNN dated July 16th, 2016 on the list of drugs, chemicals and antibiotics banned or restricted to use in Vietnamese aquaculture. Retrieved on November 30, 2019 from http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=1&mode=detail&document_id=186403 on November 30, 2019 (in Vietnamese).

Dao N. L. A., Phu T. M., Douny C., Quetin-Leclercq J., Hue B. T. B, Bach L. T., Nhu T. Q., Hang B. T. B., Huong D. T. T., Phuong N. T., Kestemont P. & Scippo M.-L. (2020). Screening and comparative study of *in vitro* antioxidant and antimicrobial activities of ethanolic extracts of selected Vietnamese plants. International Journal of Food Properties., 23(1): 481-496. DOI: 10.1080/10942912.2020.1737541.

Nguyen Phu Hoa (2012). The use of Yucca extract in aquaculture. In: Truong Quoc Phu (Ed.). Principals and technique in aquaculture. Agriculture Publisher, HCMC: 170 pages (in Vietnamese).

Nguyen Quoc Thinh, Masashi Maita & Tran Minh Phu (2020). Status of diseases, drugs and chemicals use in snakehead (*Channa striata*) culture in An Giang and Tra Vinh provinces. Can Tho University Journal of Science. Specialized in Aquaculture. 56(2): 179-184 (in Vietnamese). DOI: 10.22144/ctu.jsi.2020.020.

Nguyen Quoc Thinh, Tran Minh Phu, Huynh So Ni, Sebastien Quennery, Do Thi Thanh Huong, Nguyen Thanh Phuong, Patrick Kestemont & Marie Louise Scippo (2014). Situation of chemicals used in rice-fish, stripped catfish cultured in pond and red tilapia cultured in cage in Mekong Delta Can Tho University Journal of Science. 2: 278-283 (in Vietnamese).

Nhu T. Q., Dam N. P., Hang B. T. B., Hue B. T. B., Scippo M.-L., Phuong N. T., Quetin-Leclercq J., & Kestemont P. (2020). Immunomodulatory potential of extracts, fractions and pure compounds from *Phyllanthus amarus* and *Psidium guajava* on striped catfish (*Pangasianodon hypophthalmus*) head kidney leukocytes. Fish and Shellfish Immunology. DOI: 10.1016/j.fsi.2020.05.051.

Nhu T. Q., Hang B. T. B., Hue B. T. B., Quetin-Leclercq J., Scippo M.-L., Phuong N. T., & Kestemont P. (2019). Plant extract-based diets differently modulate immune responses and resistance to bacterial infection in striped catfish (*Pangasianodon hypophthalmus*). Fish

and Shellfish Immunology. 92: 913-924. DOI: 10.1016/j.fsi.2019.07.025.

Nhu T. Q., Hang B. T. B., Vinikas A., Hue B. T. B., Quetin-Leclercq J., Scippo M.-L., Phuong N. T., & Kestemont P. (2019). Screening of immuno-modulatory potential of different herbal plant extracts using striped catfish (*Pangasianodon hypophthalmus*) leukocyte-based in vitro tests. Fish and Shellfish Immunology. 93: 296-307. DOI: 10.1016/j.fsi.2019.07.064.

Ocheng F., Bwanga F., Joloba M., Borg-Karlson A.-K., Gustafsson A. & Obua C. (2014). Antibacterial activities of extracts from Ugandan medicinal plants used for oral care. Journal of ethnopharmacology., 155(1): 852-855. DOI: 10.1016/j.jep.2014.06.027.

Pham Minh Duc, Tran Thi Thanh Hien & Tran Ngoc Tuan (2012). An investigation on pathogen infection to cultured snakehead (*Channa striata*) in An Giang and Dong Thap provinces. Can Tho University Journal of Science. 21b: 124-132 (in Vietnamese).

Phan L. T., Bui T. M., Nguyen T. T., Gooley G. J., Ingram B. A., Nguyen H. V., Nguyen P. T. & De Silva S. S. (2009). Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus* in the Mekong Delta, Vietnam. Aquaculture. 296(3-4): 227-236. DOI: 10.1016/j.aquaculture.2009.08.017.

Phu T. M., Phuong N. T., Dung T. T., Hai D. M., Son V. N., Rico A., Clausen J. H., Madsen H., Murray F., & Dalsgaard A. (2016). An evaluation of fish health-management practices and occupational health hazards associated with Pangasius catfish (*Pangasianodon hypophthalmus*) aquaculture in the Mekong Delta, Vietnam. Aquaculture Research. 47(9): 2778-2794. DOI: 10.1111/are.12728.

Ström G. H., Björklund H., Barnes A. C., Da C. T., Nhi N. H. Y., Lan T. T., Magnussion U., Haldén A. N., & Boqvist, S. (2019). Antibiotic Use by Small-Scale Farmers for Freshwater Aquaculture in the Upper Mekong Delta, Vietnam. Journal of Aquatic Animal Health. 31(3): 290-298. DOI: 10.1002/aah.10084.

Sukumaran V., Park S. C. & Giri S. S. (2016). Role of dietary ginger Zingiber officinale in improving growth performances and immune functions of *Labeo rohita* fingerlings. Fish and Shellfish Immunology., 57: 362-370. DOI: 10.1016/j.fsi.2016.08.056.

Tekwu E. M., Pieme A. C. & Beng V. P. (2012). Investigations of antimicrobial activity of some Cameroonian medicinal plant extracts against bacteria and yeast with gastrointestinal relevance. Journal of Ethnopharmacology. 142(1): 265-273. DOI: 10.1016/j.jep.2012.05.005.

Tran Hoang Tuan, Tran Ngoc Hai, Truong Hoang Minh, Huynh Van Hien, Robert S. Pomeroy & Nguyen Tuan Loc (2014). Assessment on production efficiency and weather change impacts on snakehead pond culture in An Giang and Tra Vinh provinces. Can Tho University Journal of Science. Specialized in Aquaculture: 141-149 (in Vietnamese).

Tran Minh Phu, Nguyen Tam Em, Nguyen Quoc Thinh, Phung Thi Truc Ha, Nguyen Khanh Nam, Do Thi Thanh Huong & Nguyen Thanh Phuong (2017). The use of drug, chemical, and probiotic in red tilapia (*Oreochromis* sp.) cage culture in Mekong Delta, Vietnam. Can Tho University Journal of Science. 51b: 80-87 (in Vietnamese).