

Immunization of Basa fish (*Pangasius bocourti*) against *Ichthyophthirius multifiliis* with live and sonicated trophonts

Uawonggul N.^{1*}; Rattanamalee C.¹; Daduang S.²

Received: September 2016

Accepted: April 2017

Abstract

The high density of Basa fish (*Pangasius bocourti*) culture leads to outbreaks of *Ichthyophthirius multifiliis* (Ich), also known as white spot disease. In this research, immunization of Basa fish against Ich with live and sonicated trophonts by intraperitoneal (IP) injection was investigated. Anti-Ich antibody titer was determined using ELISA and Western immunoblotting 21 days post immunization. The results revealed that pre-immunized fish, non-immunized fish and fish immunized with bovine serum albumin (BSA) at a concentration $65 \mu\text{g g}^{-1}$ fish did not show specific antibody against Ich. 21 days post immunization, fish immunized with live trophonts exhibited higher anti-Ich antibody titer than fish immunized with sonicated trophonts at the same antigen concentration. Fish immunized with $65 \mu\text{g}$ trophonts protein/g fish live trophonts showed the highest titer 1:1,000 ($p < 0.05$). The results from Western immunoblotting showed two parasite protein bands of 66 kDa and < 14 kDa, which reacted with antibodies from serum of immune fish. No fish in the non-immunized group survived. At the same concentration of antigen ($65 \mu\text{g g}^{-1}$), fish immunized with live trophonts exhibited the highest survival rate, $63.33 \pm 5.77\%$ ($p < 0.05$). Therefore, these results are the Basa fish immunizing procedure will be the way to conduct immunization against Ich to prevent disease outbreaks in aquaculture.

Keywords: *Pangasius bocourti*, *Ichthyophthirius multifiliis*, Immunization

1-Faculty of Science, Nakhon Phanom University, Nakhon Phanom, 48000, Thailand

2-Department of Pharmacology and toxicology, Faculty of Pharmaceutical Sciences, Khon Kaen University, Khon Kaen, 40002, Thailand

*Corresponding author's Email: nunthaua@npu.ac.th

Introduction

Basa fish or Asian catfish (*Pangasius bocourti*) is a freshwater fish in the family Pangasiidae found in Southeast Asia, especially in the Mekong and Chao Phraya Rivers. This fish has an important economic impact in Nakhon Phanom Province, Thailand. It is cultured in cages in the Mekong basin and exported to the other Southeast Asian countries as well as to Europe and Russia. It is prized for its white meat, tender texture, good taste, low fat and easily digestible protein (Hung *et al.*, 2002; Jiwyam, 2010; Sriphairoj *et al.*, 2010). Increasing consumer demand has encouraged rapid extension of Basa fish farming. This form of aquaculture involves high density fish culture which unfortunately has led to disease outbreaks (Dickerson and Findly, 2014). Antibiotics as oxytetracycline are used to control and treat this disease. Their dosages are usually high which promotes antibiotic resistance in microorganisms, low meat quality and environmental pollution (Saini *et al.*, 2014). White spot disease is caused by *Ichthyophthirius multifiliis* (Ich) and is commonly found in native and farmed freshwater fish. Diseased native fish can spread Ich to farmed fish (Xu *et al.*, 2013). Many infections have been reported in fish cultures, especially in tropical and subtropical regions (Scholz, 1999). Ich can spread rapidly in poor quality water or unsuitable culture conditions (Osman *et al.*, 2009). In Ich infected fish skin and gills are damaged leading to fish mortality, especially in fingerlings. This represents a significant economic loss

in aquaculture (Martins *et al.*, 2011). Currently, chemicals such as formalin, methylene blue, copper sulfate, potassium permanganate, hydrogen peroxide and acetic acid are used to treat fish against this parasite (Xiao-Feng *et al.*, 2014; Song *et al.*, 2015). The most effective chemical used for treatment is malachite green, which was banned due to its toxicity (Song *et al.*, 2015). The chemicals presently used are applied for treatment only after the presence of parasite has been detected on fish skin. Thus, the treatment is not effective enough (Xu *et al.*, 2008a, b). Moreover, Ich treatment is more complicated due to its life cycle. This parasite has a temperature dependent life cycle that includes three stages, theront, trophont and tomont (Shinn *et al.*, 2009). Tomont referred as cyst of Ich in a free form living in an aquatic environment. Cyst walls block chemical penetration making treatment difficult. Infected fish may acquire systemic and mucosal immunity against Ich (Swennes *et al.*, 2007; Alvarez-Pellitero, 2008). Fish vaccination is an alternative choice for parasite prevention that is harmless to the environment. Several studies reported successful fish immunization against Ich. Dalgaard *et al.* (2002) reported protection against Ich in rainbow trout (*Oncorhynchus mykiss*) after immunization with sonicated formalin killed trophonts. Heidarieh *et al.* (2014) reported an immune response against Ich in rainbow trout immunized with irradiated trophonts. Xu *et al.* (2008a) reported immunization of Nile tilapia (*Oreochromis niloticus*) against Ich by

immersing them in water containing live theronts and sonicated trophonts as well as by intraperitoneal (IP) injection at levels of 20,000 theronts per fish and 65 μg trophont protein g^{-1} fish, respectively. The results showed that anti-Ich antibody of fish immunized by immersion in water containing live theronts and by IP injection of live theronts and sonicated trophonts had significantly higher anti-Ich antibodies than fish immunized with sonicated trophonts by immersion and non-immunized fish. Moreover, Xu *et al.* (2008b) reported that the channel catfish immunized with formalin killed and freeze-thawed trophonts did not produced anti-Ich antibodies and were infected by Ich. Osman *et al.* (2009) immunized Goldfish (*Carassius auratus*) against Ich at levels 20,000 live theronts per fish, 2,000 trophonts per fish and 65 μg sonicated trophonts/ g fish by immersion and IP injection. Fish immunized with theronts by immersion and IP injection showed higher anti-Ich antibodies and survival rates than fish immunized with trophonts by immersion and IP injection. Martins *et al.* (2011) evaluated temperature effects on *Ictalurus punctatus* immune response against live theronts of Ich and found that immunized fish at low temperature had high mortality and no anti-Ich antibody production. However, immunity of Basa fish against Ich is not clear. Therefore, this study aims to investigate immune response of Basa fish against Ich after immunization with live and sonicated trophonts.

Materials and methods

Fish, parasite and water quality

Basa fish, having a mean length of 8.9 ± 0.7 cm mean, mean weight of 11.30 ± 1.93 g and no previous infection with Ich were cultured in glass tanks at a density of 30 fish 100 L^{-1} of dechlorinated tap water. Fish were distributed among 8 treatments with 2 replicates and were fed 40% crude protein at a level of 5% of their body weight daily using commercial fish feed. Infected Basa fish were obtained from Nakhon Phanom Inland Fisheries Research and Development Center. These infected fish were rinsed with distilled water and fish skin was gently scraped to isolate Ich. Water quality measurement and water exchange were performed every three days. Water temperature, pH and dissolve oxygen (DO) were determined using a pH meter (HI-98127, Hanna, UK) and DO meter (HI9147, Hanna, UK), respectively. Ammonia and nitrite concentrations were measured using ammonia and nitrite test kits (Advance Pharma, Thailand). During the experiment, water temperature, pH, DO, ammonia and nitrite concentrations were 31.3 ± 2.4 °C, 7.13 ± 0.30 , 6.8 ± 0.5 mg L^{-1} , 0.2 ± 0.1 mg L^{-1} , 0.2 ± 0.2 mg L^{-1} , respectively.

Antigen preparation

Antigen preparation was modified from Xu *et al.* (2008a). Trophonts were separated from fish skin and mucus then pooled in a plastic tube. The collected trophonts were counted with Sedgewick Rafter counting chamber (SPI Supplies, USA) and concentrated

by centrifugation at 1,000 rpm for 5 min. Then the supernatant was discarded and the pellet resuspended in PBS buffer, pH 7.4. The trophont suspension was used as the first antigen (live trophonts). Another antigen (sonicated trophonts) was prepared by sonicating a trophont suspension for 1 min on ice. The protein concentration in live and sonicated trophonts was measured using a spectrophotometric method (HALO RB-10, Dynamica, Australia) (Bradford, 1976).

Immunization

Fish were divided into 8 treatments and immunized by IP injection with 100 μ L of antigen. Antigen was mixed with Freund's adjuvant before injection. The first treatment was non-immunized fish. The second treatment was immunized with bovine serum albumin (BSA) at 65 μ g protein g^{-1} fish. First and second treatments were used as negative controls. Fish in treatments 3-5 were immunized with live trophonts at 45, 55 and 65 μ g protein g^{-1} fish, while fish in treatments 6-8 were immunized with sonicated trophonts at same respective protein concentrations.

Serum sampling

Before immunization, fish serum was kept as pre-immunized. Twenty one days post immunization, five fish in each of treatments 1-8 were randomly selected for serum sampling. Fish blood was sampled from the base of the tail. Blood coagulation was allowed at 4 °C overnight and then the samples were centrifuged at 10,000 rpm at 4 °C for 10 min (Z236K, Hermle, Germany). The

antibody titer against Ich in the collected serum was determined using ELISA and Western immune blotting.

ELISA

ELISA was performed according to Kuendee *et al.* (2015) with slight modification. Ich was diluted in a carbonate buffer, pH 9.5 to 20 μ g mL^{-1} . Each well of 96-well polystyrene plates (Nunc, Denmark) was coated with 50 μ L of the diluted Ich solution. The coated plate was washed 3 times with TBST and blocked with 5% skim milk (Scharalau, Spain). Then, the wells were added with various serial dilutions of fish serum and incubated at 37 °C for 1 hr. After that, it was washed 3 times with TBST and incubated with mouse anti-Basa fish IgM antiserum (1:10⁵) at 37 °C for 1 hr, followed by washing 3 times with TBST again. Afterward, the plate was incubated with conjugated anti-mouse IgG linked with alkaline phosphatase (1:5 \times 10³, Zymed, USA) at 37 °C for 1 hr. Subsequently, it was washed 3 times with TBST and 3 times with TBS. 100 μ L of 1 mg mL^{-1} p-Nitrophenyl phosphate (Amersham, Canada) was added as substrate. Next, the absorbance was determined at 405 nm using a Microplate Reader (Bio-Rad, USA). The titer in this study was defined as the highest dilution that still showed a positive result.

Western immunoblotting

Ich proteins were separated with 12% separating gel and 4% stacking gel with constant voltage at 150 V. Then, the proteins were transferred from SDS-

PAGE gel onto a nitrocellulose membrane. After this transfer, the membrane was divided as a part was allocated for protein molecular weight estimation and a part of the membrane was used for samples immunoblotting. The marker part of the membrane part stained with 0.1% Amido Black, whereas the sample part of the membrane was incubated in 5% skim milk. After incubation, the sample part of the membrane was further incubated with a various serial dilution of fish serum as 1:10, 1:10², 1:10³, 1:10⁴, 1:10⁵ and 1:10⁶ at room temperature for 1 hr and washed 3 times with TBST. Next, it was incubated with anti-Basa fish serum (1:10⁴) at room temperature for 1 hr. After that, the membrane was washed 3 times with TBST and incubated with anti-mouse IgG linked with alkaline phosphatase (1:5×10³) at room temperature for 1 hr. Subsequently, it was washed 3 times with TBST and 3 times with TBS. Then, the membrane was soaked twice in a substrate buffer, pH 9.5 and added with a NBT/BCIP substrate solution (Bio-Rad, USA). Finally, this membrane was agitated in a substrate solution until the protein band could be observed.

Challenge with Ich

Twenty one days post immunization, 10 fish from each group were transferred to new glass tank containing with 100 L of dechlorinated tap water. These fish were challenged with 10⁴ theronts fish⁻¹ for 2 hr. White spots on the fish skin and scratching behavior against the walls of the tank were observed and

recorded. Two days post challenge, three fish from each group were randomly selected for estimated the number of parasites as described previously by Osman *et al.* (2009). The parasites infection level was assessed by scoring, no infection = 0, <50 trophonts fish⁻¹ = 1, 50-100 trophonts fish⁻¹ = 2 and >100 trophonts fish⁻¹ = 3. One week after challenge, the survival rate of fish in each tank was determined. The experiment was done in duplicate.

Statistical analysis

The data was analyzed using SPSS for Windows Version 17.0. Parameter values were reported as mean±standard deviation. The differences in parameter values of each treatment were examined using one-way ANOVA with Scheffé post hoc tests ($p<0.05$).

Results

Anti-Ich antibody titer

Anti-Ich antibody was not detected in pre-immunized fish whereas it was detected in fish serum that was sampled from treatments 3-8 (Table 1). Non-immunized fish and fish immunized with BSA did not produce antibody against Ich (Table 1). Fish immunized with live trophonts revealed higher antibody titers against Ich than those immunized with sonicated trophonts. Fish immunized with live trophonts at a protein concentration 65 µg g⁻¹ fish showed the highest antibody titer against Ich at a dilution 1:1,000 ($p<0.05$). These fish had significantly higher anti-Ich antibody titers than fish immunized with sonicated trophonts at the same protein concentration.

Moreover, they had significantly higher antibody titer against Ich than fish immunized with live or sonicated trophonts at 45 and 55 $\mu\text{g protein g}^{-1}$ fish. Fish immunized with sonicated trophonts at 65 $\mu\text{g protein g}^{-1}$ fish showed antibody titers at a 1:100 dilution similar to fish immunized with live trophonts at 45 and 55 $\mu\text{g protein g}^{-1}$ fish. Fish immunized with sonicated

trophonts at 45 and 55 $\mu\text{g protein g}^{-1}$ fish showed antibody titers against Ich at a 1:10 dilution. However, no statistical difference was found between antibody titers from fish immunized with live trophonts at 45 and 55 $\mu\text{g protein g}^{-1}$ fish including fish immunized with sonicated trophonts at 45 and 55 $\mu\text{g protein g}^{-1}$ fish.

Table 1: ELISA absorbance at 405 nm of non-immunized and immunized Basa fish (*Pangasius bocourti*) serum 21 days post immunization.

Treatment	Dilution	A405nm
Pre-immunized	1:10	0.000 \pm 0.000 ^{a*}
Non-immunized	1:10	0.032 \pm 0.005 ^a
Immunized with BSA at 65 $\mu\text{g g}^{-1}$ fish	1:10	0.031 \pm 0.006 ^a
	1:10	0.302 \pm 0.032 ^b
	1:10 ²	0.147 \pm 0.016 ^c
Immunized with live trophonts at 45 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.043 \pm 0.008 ^a
	1:10 ⁴	0.009 \pm 0.006 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a
	1:10	0.334 \pm 0.077 ^b
	1:10 ²	0.196 \pm 0.045 ^c
Immunized with live trophonts at 55 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.077 \pm 0.019 ^a
	1:10 ⁴	0.017 \pm 0.005 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a
	1:10	0.369 \pm 0.060 ^b
	1:10 ²	0.201 \pm 0.051 ^b
Immunized with live trophonts at 65 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.114 \pm 0.015 ^c
	1:10 ⁴	0.033 \pm 0.002 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a
	1:10	0.183 \pm 0.013 ^c
	1:10 ²	0.049 \pm 0.010 ^a
Immunized with sonicated trophonts at 45 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.006 \pm 0.003 ^a
	1:10 ⁴	0.000 \pm 0.000 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a
	1:10	0.218 \pm 0.008 ^c
	1:10 ²	0.081 \pm 0.010 ^a
Immunized with sonicated trophonts at 55 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.024 \pm 0.004 ^a
	1:10 ⁴	0.005 \pm 0.004 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a
	1:10	0.256 \pm 0.038 ^b
	1:10 ²	0.173 \pm 0.021 ^c
Immunized with sonicated trophonts at 65 $\mu\text{g g}^{-1}$ fish	1:10 ³	0.092 \pm 0.016 ^a
	1:10 ⁴	0.006 \pm 0.004 ^a
	1:10 ⁵	0.000 \pm 0.000 ^a

*Different superscripts indicate statistically significant differences.

The results determined using western immunoblotting were similar to ELISA. Anti-Ich antibody was not detected in pre-immunized fish, non-immunized

fish and fish immunized with BSA. Fish immunized with live or sonicated trophonts showed specific protein bands at approximately 66 kDa and below 14

kDa (Fig.1A and 1B). Fish immunized with live and sonicated trophonts at a concentration $65 \mu\text{g protein g}^{-1}$ fish indicated the highest titer, 1:100. Both of fish immunized with live and sonicated trophonts at a concentration

45 and $55 \mu\text{g protein g}^{-1}$ fish revealed a titer at a 1:10 dilution. However, protein band intensity of fish immunized with live trophonts was higher than that of fish immunized with sonicated trophonts.

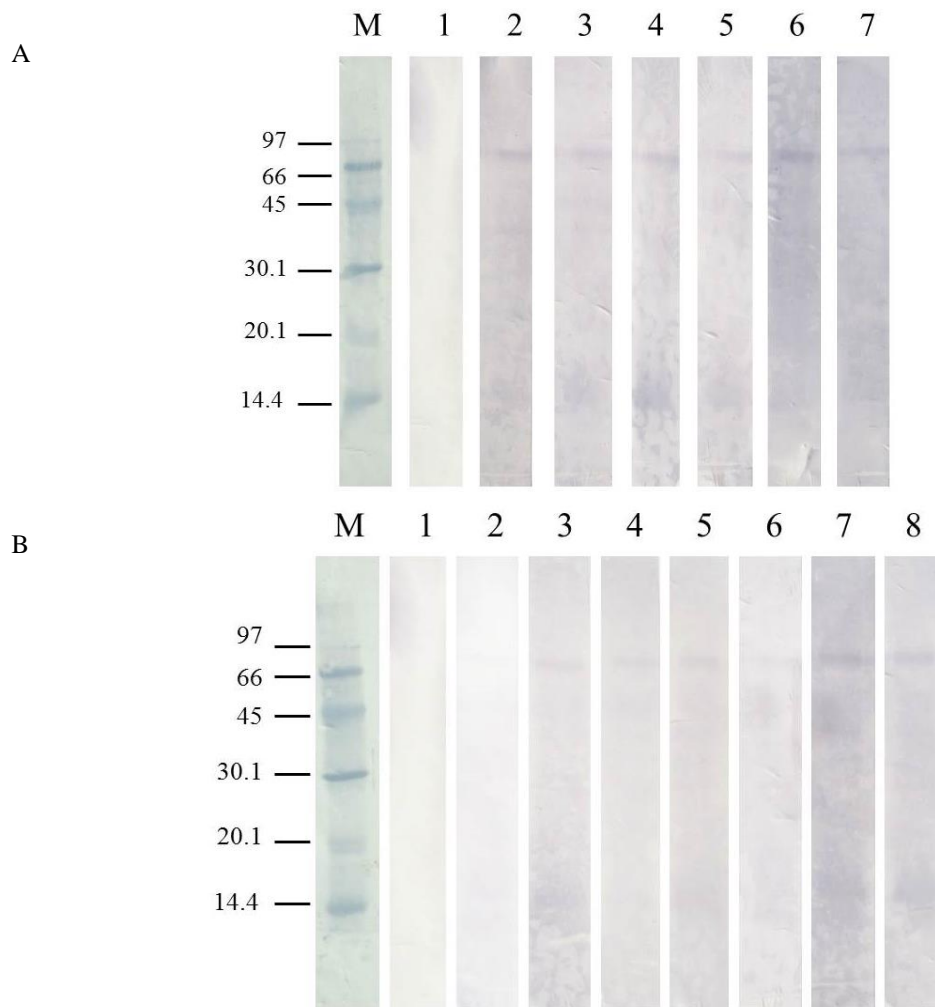


Figure 1: Western immunoblotting of immunized Basa fish (*Pangasius bocourti*) serum 21 days post immunization. (A) Fish immunized with live trophonts, lane M: marker, lane 1: pre-immunized fish at dilution 1:10, lanes 2 and 3: immunized with $45 \mu\text{g protein g}^{-1}$ fish at dilution 1:10 and 1:100, lanes 4 and 5: immunized with $55 \mu\text{g protein g}^{-1}$ fish at dilution 1:10 and 1:100 and lanes 6 and 7: immunized with $65 \mu\text{g protein/g}$ fish at dilution 1:10 and 1:100. (B) fish immunized with sonicated trophonts lane M: marker, lane 1: non-immunized serum at dilution 1:10, lane 2 immunized with BSA $65 \mu\text{g protein g}^{-1}$ fish, lanes 3 and 4: immunized with $45 \mu\text{g protein g}^{-1}$ fish at dilutions 1:10 and 1:100, lanes 5 and 6: immunized with $55 \mu\text{g protein g}^{-1}$ fish at dilution 1:10 and 1:100 and lanes 7 and 8: immunized with $65 \mu\text{g protein g}^{-1}$ fish at dilution 1:10 and 1:100.

Survival rate of fish with Ich

After challenge with Ich for two days, the number of parasites on the fish was estimated. The results showed that Non-immunized fish and fish immunized with BSA had similar higher parasites infection level per fish than fish immunized with live and sonicated trophonts. Fish immunized with live trophonts at a level of $65 \mu\text{g g}^{-1}$ fish had the lowest number of parasites per fish (Table 2). Non-immunized fish and fish immunized with BSA showed heavy infection, whereas fish immunized with live or sonicated trophonts revealed light infection. First dead fish in Non-immunized group was found three days post challenge while fish immunized with live trophonts was found dead four days post challenge. After challenge with Ich for one week, Non-immunized

fish showed the highest mortality, 100% (Table 2). All non-immunized fish has been found dead four days after challenge. Fish immunized with BSA had a low survival rate of 3.33% (Table 2). The survival rate of fish immunized with live trophonts at a level of $65 \mu\text{g g}^{-1}$ fish had the highest and most statistically significant difference (Table 2) ($p < 0.05$). There were no statistically significant differences between fish immunized with live and sonicated trophonts at lower protein concentrations. Two weeks post challenge, all survive fish that immunized with live and sonicated trophonts at a level of 45, 55 and $65 \mu\text{g g}^{-1}$ fish were still survive while all survive fish that immunized with BSA was mortal (data not shown).

Table 2: Parasites infection level per fish two days post challenge and survival rate one week post challenge of non-immunized and immunized Basa fish (*Pangasius bocourti*).

Treatment	parasites infection level	Survival rate (%)
Non-immunized	3	$0.00 \pm 0.00^{\text{a}*}$
Immunized with BSA at $65 \mu\text{g g}^{-1}$ fish	3	$3.33 \pm 5.77^{\text{a}}$
Immunized with live trophonts at $45 \mu\text{g g}^{-1}$ fish	2	$33.33 \pm 5.77^{\text{b}}$
Immunized with live trophonts at $55 \mu\text{g g}^{-1}$ fish	2	$40.00 \pm 10.00^{\text{b}}$
Immunized with live trophonts at $65 \mu\text{g g}^{-1}$ fish	1	$63.33 \pm 5.77^{\text{c}}$
Immunized with sonicated trophonts at $45 \mu\text{g g}^{-1}$ fish	2	$30.00 \pm 10.00^{\text{b}}$
Immunized with sonicated trophonts at $55 \mu\text{g g}^{-1}$ fish	1	$33.33 \pm 15.28^{\text{b}}$
Immunized with sonicated trophonts at $65 \mu\text{g g}^{-1}$ fish	1	$43.33 \pm 5.77^{\text{b}}$

*Different superscripts indicate the statistical significant differences.

Discussion

The anti-Ich antibody titers observed in this study were similar to other fish immunization using the same method of antigen injection (Dalgaard *et al.*, 2002; Xu *et al.*, 2004; Xu *et al.*, 2008a; Xu *et al.*, 2008b; Osman *et al.*, 2009; Martins *et al.*, 2011). Intraperitoneal injection was potential method for fish

immunization (Burk *et al.*, 1990). Non-immunized fish and fish immunized with BSA did not produce anti-Ich antibody according to a previous report (Xu and Klesius, 2013). Fish immunized with live trophonts showed higher antibody titers than that of fish immunized with sonicated trophonts. These results indicated that

live trophonts exhibited better antigenicity than sonicated trophonts. Therefore, fish immunized with live trophonts produced significantly higher antibody titers than fish immunized with inactivated trophonts. These results are in accordance with previous studies of immunization with inactivated antigens as formalin killed and freeze-thawed trophonts that reported lower antibody production than when immunized with live antigens (Xu *et al.*, 2008a, b). However, live trophonts that used as antigen has the advantage when compare with live theronts that used as antigen in the previous study because antigen preparation is less complicated. Moreover, the antigen dose had an effect on antibody production. The antibody of fish immunized with 65 μg of live and sonicated trophont protein g^{-1} fish revealed significantly higher antibody than that of fish immunized with 45 and 55 μg trophont protein g^{-1} fish. However, no statistical difference of antibody titer was found in fish immunized with live and sonicated trophonts at concentrations of 45 and 55 μg g^{-1} fish. These results agree with a previous study of antibody production for immune protection, which found that a suitable concentration of antigen was required for immune protection (Xu *et al.*, 2008b). In previous studies, fish immunoglobulin (Ig) as IgM and IgD were produced in immunized channel catfish, while IgM and IgT were detected in rainbow trout (Olsen *et al.*, 2011; Heinecke and Buchman, 2013; Xu *et al.*, 2016). From this, we hypothesized that IgM should be

produced in Basa fish as a serum antibody. Moreover, another immune response against Ich, increased white blood cell counts, was also found in fish (Abdel-Hafez *et al.*, 2014; Tancredo *et al.*, 2015). We suggest a study of immunological parameter responses as a future study. Furthermore, multiple serotypes immobilization antigen of Ich are found and have been classified into five serotypes referred to serotypes A, B, C, D and E (Dickerson and Clark, 1996). There are the differences in virulence and protein molecular weight between serotypes. For example, serotypes A infected fish at a lower level than serotypes D but all infected fish with serotypes A died. In the previous study, cross-reactivity of anti-Ich antibody with different serotypes of immobilization antigen was found (Swennes *et al.*, 2007). Probably, anti-Ich antibody from immunized fish with trophonts in this study may be reacting with multiple serotypes immobilization antigen.

The results obtained from western immunoblotting revealed that fish antibody could react with Ich antigen protein at approximately 66 kDa and below 14 kDa. In contrast with a previous report, a protein approximately 55 kDa acting as a surface immobilization antigen of Ich was not found in this research (Wang and Dickerson, 2002; Maki and Dickerson, 2003). Moreover, proteins at approximately 34, 39, 45 and 46 kDa acting as antigens against Ich membrane proteins play an important role in fish immunization (Wang *et al.*, 2002). These proteins were not found in

the current study. We theorize that the proteins at approximately 66 kDa and below 14 kDa should be important Ich antigens in Basa fish. We also hypothesize that the proteins at approximately 66 kDa may promote a surface immobilization antigen against Ich. However, the proteins below 14 kDa should be the interaction of antibody with the reduced parts of proteins as break down products from the immobilization antigens (i-antigens; ranging in size from 40 to 70 kDa) (Lin *et al.*, 1996; Swennes *et al.*, 2006).

In this study, non-immunized fish and fish immunized with BSA showed heavy infection and died after few days. This was similar to results of a study of infected Nile Tilapia that exhibited a mean of five days to death (Xu *et al.*, 2014). The immunized fish could produce protective antibody against Ich. They had high anti-Ich antibody titers and exhibited light infections with high survival rates. Fish immunized with high level of antigen had the lowest number of parasites infection per fish that exhibit the quantitative exact result of protection. The results showed that the immune response and immune protection were proportional to anti-Ich antibody. However, the fish were not fully protected and this may be due to an in-sufficient level of anti-Ich antibodies or other factors, as was observed in other studies (Xu *et al.*, 2008a; Osman *et al.*, 2009). We proposed that Ich successfully penetrate the epithelium of immune fish but are forced to exit due to cutaneous antibody attachment.

In conclusion, Basa fish immunized with live and sonicated trophonts by IP injection showed an immune response against Ich. Basa fish immunized with live trophonts produced higher anti-Ich antibody titers and had greater survival rates than those of fish immunized with sonicated trophonts. Therefore, immunization of Basa fish with live and sonicated Ich by IP injection enhance protection against this parasite.

Acknowledgement

This research was supported by National Research Council of Thailand (NRCT). The authors wish to thank Siwatch Sakulwongworachote for excellent support in maintenance of the Basa fish. The authors also thank Uraiwan Piasoongnoen, Nakhon Phanom Inland Fisheries Research and Development Center, for parasite collection.

References

- Abdel-Hafez, G., Lahnsteiner, F., Mansour, N. and Licek, E., 2014.** Pathophysiology of *Ichthyophthirius multifiliis* infection in rainbow trout (*Oncorhynchus mykiss*) and chub (*Leuciscus cephalus*). *Journal of Comparative Pathology*, 151, 394-399.
- Alvarez-Pellitero, P., 2008.** Fish immunity and parasite infections: from innate immunity to immunoprophylactic prospects. *Veterinary Immunology and Immunopathology*, 126, 171-198.
- Bradford, M.M., 1976.** Rapid and sensitive method for quantitation of microgram quantities of protein

- utilising principle of protein dye binding. *Analytical Biochemistry*, 72, 248-254.
- Burk, M.A., Clark, T.G. and Dickerson, H.W., 1990.** Immunization of channel catfish, *Ictalurus punctatus* Rafinesque, against *Ichthyophthirius multifiliis* (Fouquet): killed versus live vaccines. *Journal of Fish Diseases*, 13, 401-410.
- Dalgaard, M., Buchman, K. and Li, A., 2002.** Immunization of rainbow trout fry with *Ichthyophthirius multifiliis* sonicate: protection of host and immunological changes. *Bulletin- European Association of Fish Pathologists*, 22(5), 288-297.
- Dickerson, H.W. and Clark, T.G., 1996.** Immune response of fishes to ciliates. *Annual Review of Fish Diseases*, 6, 107-120.
- Dickerson, H.W. and Findly, R.C., 2014.** Immunity to *Ichthyophthirius* infections in fish: A synopsis. *Developmental and Comparative Immunology*, 43, 290-299.
- Heidarieh, M., Hedayatirad, M., Mirvaghefi, A.R., Diallo, A., Mousavi, S., Sheikhzadeh, N. and Shahbazfar, A.A., 2014.** Effect of gamma irradiation on inactivation of *Ichthyophthirius multifiliis* trophonts and its efficacy on host response in experimentally immunized rainbow trout (*Oncorhynchus mykiss*). *Turkish Journal of Veterinary and Animal Sciences*, 38, 388-393.
- Heinecke, R.D. and Buchman, K., 2013.** Inflammatory response of rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) larvae against *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 34, 521-528.
- Hung, L.T., Tuan, N.A., Cacot, P. and Lazard, J., 2002.** Larval rearing of the Asian catfish, *Pangasius bocourti* (Siluroidei, Pangasiidae): alternative feeds and weaning time. *Aquaculture*, 212, 115-127.
- Jiwyam, W., 2010.** Growth and compensatory growth of juvenile *Pangasius bocourti* Sauvage, 1880 relative to ration. *Aquaculture*, 306, 393-397.
- Kuendee, N., Klaynongsruang, S., Bunyatratchata, W., Tengjaroenkul, B., Ngamcharoen, K., Daduang, J., Ungarreevittaya, P. and Daduang, S., 2015.** Ontogeny of Nile tilapia (*Oreochromis niloticus*) immunoglobulin type M antibody response. *Israeli Journal of Aquaculture-Bamidgeh*, 67.
- Lin, T.L., Clark, T.G. and Dickerson, H., 1996.** Passive immunization of channel catfish (*Ictalurus punctatus*) against the ciliated protozoan parasite *Ichthyophthirius multifiliis* by use of murine monoclonal antibodies. *Infection and Immunity*, 64(10), 4085-4090.
- Maki, J.L. and Dickerson, H.W., 2003.** Systemic and cutaneous mucus antibody response of channel catfish immunized against the protozoan parasite *Ichthyophthirius multifiliis*. *Clinical and Diagnostic Laboratory Immunology*, 10(5), 876-881.
- Martins, M.L., Xu, D.H., Shoemaker, C.A. and Klesius, P.H., 2011.** Temperature effects on immune

- response and hematological parameters of channel catfish *Ictalurus punctatus* vaccinated with live theronts of *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 31, 774-780.
- Olsen, M.M., Kania, P.W., Heinecke, R.D., Skjoedt, K., Rasmussen, K.J. and Buchman, K., 2011.** Cellular and humoral factors involved in the response of rainbow trout gills to *Ichthyophthirius multifiliis* infections: molecular and immunohistochemical studies. *Fish and Shellfish Immunology*, 30, 859-869.
- Osman, H.A.M., Monier, M.M., Abd El Ghany, O.A., Ibrahim, T.B. and Ismail, M.M., 2009.** Protection of goldfish (*Carassius auratus*) against *Ichthyophthirius multifiliis* by immunization with live theronts, trophonts and sonicated trophonts. *Global Veterinaria*, 3(4), 329-334.
- Saini, V.P., Ojha, M.L., Gupta, M.C., Nair, P., Sharma, A. and Luhar, V., 2014.** Effect of dietary on growth performance and disease resistance in *Labeo rohita* (Ham.) fingerlings. *International Journal of Fisheries and Aquatic Studies*, 1(6), 7-11.
- Scholz, T., 1999.** Parasites in cultured and feral fish. *Veterinary Parasitology*, 84, 317-335.
- Shinn, A.P., Picon-Camacho, S.M., Bawden, R. and Taylor, N.G.H., 2009.** Mechanical control of *Ichthyophthirius multifiliis* Fouquet, 1876 (Ciliophora) in a rainbow trout hatchery. *Aquacultural Engineering*, 41(3), 152-157.
- Song, K., Ling, F., Huang, A., Dong, W., Liu, G., Jiang, C., Zhang, Q. and Wang, G., 2015.** *In vitro* and *in vivo* assessment of the effect of antiprotozoal compounds isolated from *Psoralea corylifolia* against *Ichthyophthirius multifiliis* in fish. *International Journal for Parasitology: Drugs and Drug Resistance*, 5, 58-64.
- Sriphairoj, K., Klinbu-nga, S., Kamonrat, W. and Na-Nakorn, U., 2010.** Species identification of four economically important *Pangasiid* catfishes and closely related species using SSCP markers. *Aquaculture*, 308, 47-59.
- Swennes, A.G., Noe, J.G., Craig Findly, R. and Dickerson, H.W., 2006.** Differences in virulence between two serotypes of *Ichthyophthirius multifiliis*. *Diseases of Aquatic Organism*, 69, 227-232.
- Swennes, A.G., Findly, R.C. and Dickerson, H.W., 2007.** Cross-immunity and antibody responses to different immobilization serotypes of *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 22, 589-597.
- Tancredo, K.R., Gonçalves, E.L.T., Brum, A., Acchile, M., Hashimoto, G.S.O., Pereira, S.A. and Martins, M.L., 2015.** Hemato-immunological and biochemical parameters of silver catfish *Rhamdia quelen* immunized with live theronts of *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 45, 689-694.
- Wang, X., Clark, T.G., Noe, J. and Dickerson, H.W., 2002.** Immunisation of channel catfish, *Ictalurus punctatus* with

- Ichthyophthirius multifiliis* immobilization antigens elicits serotype-specific protection. *Fish and Shellfish Immunology*, 13, 337-350.
- Wang, X. and Dickerson, H.W., 2002.** Surface immobilization antigen of the parasitic ciliate *Ichthyophthirius multifiliis* elicits protective immunity in channel catfish (*Ictalurus punctatus*). *Clinical and Diagnostic Laboratory Immunology*, 9(1), 176-181.
- Xiao-Feng, S., Qing-Feng, M., Yuan-Huan, K., Yu, B., Yun-Hang, G., Wei-Li, W. and Ai-Dong, Q., 2014.** Isolation of active compounds from methanol extracts of *Toddalia asiatica* against *Ichthyophthirius multifiliis* in goldfish (*Carassius auratus*). *Veterinary Parasitology*, 199, 250-254.
- Xu, D.H., Klesius, P.H. and Shelby, R.A., 2004.** Immune responses and host protection of channel catfish, *Ictalurus punctatus* (Rafinesque), against *Ichthyophthirius multifiliis* after immunization with live theronts and sonicated trophonts. *Journal of Fish Diseases*, 27, 135-141.
- Xu, D.H., Klesius, P.H. and Shoemaker, C.A., 2008a.** Protective immunity of Nile tilapia against *Ichthyophthirius multifiliis* post-immunization with live theronts and sonicated trophonts. *Fish and Shellfish Immunology*, 25, 124-127.
- Xu, D.H., Klesius, P.H. and Shoemaker, C.A., 2008b.** Effect of immunization of channel catfish with inactivated trophonts on serum and cutaneous antibody titers and survival against *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 26, 614-618.
- Xu, D.H., Shoemaker, C.A., Zhang, Q. and Klesius, P.H., 2013.** Naturally infected channel catfish (*Ictalurus punctatus*) concurrently transmit *Ichthyophthirius multifiliis* and *Edwardsiella ictaluri* to naïve channel fish. *Aquaculture*, 376-379, 133-136.
- Xu, D.H. and Klesius P.H., 2013.** Comparison of serum antibody responses and host protection against parasite *Ichthyophthirius multifiliis* between channel catfish and channel × blue hybrid catfish. *Fish and Shellfish Immunology*, 34, 1356-1359.
- Xu, D.H., Shoemaker, C.A. and LaFrentz, B.R., 2014.** Enhanced susceptibility of hybrid tilapia to *Flavobacterium columnare* after parasitism by *Ichthyophthirius multifiliis*. *Aquaculture*, 430, 44-49.
- Xu, D.H., Zhang, Q.Z., Shoemaker, C.A. and Zhang, D., 2016.** Molecular immune response of channel catfish immunized with live theronts of *Ichthyophthirius multifiliis*. *Fish and Shellfish Immunology*, 54, 86-92.