Growth and Flesh Quality of the Hybrid between
Pangasianodon hypophthalmus and *Pangasius bocourti*

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ABSTRACT

A hybrid between the female striped catfish (*Pangasianodon hypophthalmus*) and the male Asian catfish (*Pangasius bocourti*) has been commercially produced with the expectation of being fast growing with white flesh, despite lacking scientific data on its commercial traits. This study compared the growth, carcass characteristics and nutritional values of the hybrid with those of the parental species. The fingerlings of the three genetic groups (average initial weight ranged from 13.62 to 23.32 g, $P > 0.05$) were randomly stocked in nine cages (13.5 m^3 each), at a stocking density of 45 fish.m^{-3}. They had been cultured for a period of 303 d (July 2009–May 2010). The results showed inferior growth and survival rate of the hybrid relative to the parental species (specific daily growth rates = 0.60 ± 0.24, 1.23 ± 0.02, and $1.20 \pm 0.02\%$; survival rates = $37.83 \pm 5.87\%$, 83.5 ± 3.82, and $95.93 \pm 1.10\%$, for the hybrid, striped and Asian catfish, respectively, $P < 0.05$). Feed conversion ratios were not significantly different among the genetic groups (ranging between 1.26 ± 0.13 and 2.07 ± 0.71). The hybrid had the lowest dress-out (37.50%) and fillet percentage (32.15%) when compared with the parental species ($P < 0.05$). The flesh of the hybrid was identified as white based on color analysis. The firmness value was lowest in the hybrid. The hybrid had higher crude protein and ash and lower lipid contents than those of the parents.

Keywords: growth, carcass, *Pangasius* hybrid, *Pangasianodon* hybrid, white-fleshed fish

INTRODUCTION

Global demand for white fish meat, for example, Nile tilapia (*Oreochromis niloticus*) and striped catfish (*Pangasianodon hypopthalmus*) has increased rapidly (Globefish, 2011; 2012). Among the world's major exporters, Vietnam is leading in the production of striped catfish with annual production exceeding 1.2 million t (FAO, 2014) and exports valued at USD 1.5 billion (Globefish, 2013). Striped catfish has been cultured in Thailand for more than 60 yr (Boonbrahm et al., 1967). Although the Thai and Vietnamese strains of striped catfish are conspecific (Na-Nakorn and Moeikum, 2009), the meat quality of the Thai strain is not acceptable for the export market as the flesh is yellow.

Recently, Asian catfish has been promoted for commercial aquaculture in Thailand (Amornledpisan and Meng-Umpan, 2010) aiming to supply export markets. However, it is not well accepted by farmers because of its low growth

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rate, while seed production is hampered due to low fecundity (Khunchareon *et al*., 2006; Sema and Teekha, 2008).

Therefore, the hybrid between the prolific female striped catfish × male Asian catfish was produced hoping to get white-fleshed fish with an improved growth rate over Asian catfish and solving the seed insufficiency problem of Asian catfish (Imsilp, pers. comm.).

Inter-specific hybridization is used for producing fish with specific desirable traits or for a general improvement in performance (Bartley *et al*., 2001). Several hybrids have become significant species for aquaculture (for example, the hybrid of the channel catfish × blue catfish, the hybrid striped catfish, and the hybrid clariid catfish; Bartley *et al*., 2001; Na-Nakorn, 2013). However, the performance of the hybrid progenies could be variable, as some have shown undesirable characteristics (Bartley *et al*., 2001). The hybrid between the striped catfish and the Asian catfish has been produced and cultured in north-east Thailand without any scientific reports on its

commercial traits. This study is the first scientific attempt to investigate the production performance including the growth, survival, carcass quality and nutrition value of the striped catfish and Asian catfish hybrid compared to the parental species.

MATERIALS AND METHODS

Fish samples and experimental design

Fingerlings of striped catfish, Asian catfish and their hybrid (female striped catfish × male Asian catfish) were obtained from the Nakhon Phanom Inland Fisheries Research and Development Center where they had been acclimated for 30 d in cages fixed in a natural swamp (Nong-han swamp, Sakon Nakhon province). At the start of the experiment, the mean ± standard deviation initial weight of the striped catfish was 23.32 ± 4.78 g, 21.39 ± 5.59 g for the hybrid and 13.62 ± 4.33 g for the Asian catfish and these weights were not significantly different ($P > 0.05$; Table 1). Fish from each genetic group were randomly distributed into nine cages ($3 \times 3 \times 1.5$ m^3,

Table 1 Growth and carcass quality of *Pangasianodon hypophthalmus*, the hybrid and *Pangasius bocourti*.

Performance	Genetic groups		
	P. hypophthalmus	Hybrid	*P. bocourti*
Growth			
Initial weight (g)	23.32 ± 4.78^a	21.39 ± 5.59^a	13.62 ± 4.33^a
Final weight (g)	972.33 ± 204.88^a	154.56 ± 90.74^c	519.89 ± 131.90^b
SGR (% per day)	1.23 ± 0.02^a	0.60 ± 0.24^b	1.20 ± 0.02^a
FCR	1.72 ± 0.20^a	2.07 ± 0.70^a	1.26 ± 0.13^a
Survival (%)	83.5 ± 3.82^b	37.83 ± 5.89^c	95.93 ± 1.10^a
Carcass quality			
Dress-out percentage (%)	53.15 ± 5.13^a	37.50 ± 6.46^c	42.61 ± 6.56^b
Fillet percentage (%)	43.73 ± 3.03^a	32.15 ± 3.31^c	35.70 ± 5.77^b
L*	47.38 ± 2.10^b	44.81 ± 2.75^c	50.40 ± 1.39^a
a*	4.24 ± 0.69^a	-0.08 ± 0.66^b	-0.87 ± 0.64^c
b*	13.35 ± 1.37^a	7.49 ± 0.84^b	6.74 ± 1.00^c
Total carotenoid (mg.mL^{-1})	0.68 ± 0.25^a	0.46 ± 0.34^b	0.19 ± 0.09^c
Firmness (N)	2.84 ± 0.67^a	0.85 ± 0.34^c	2.34 ± 0.76^b

Means with different letters as superscripts are significantly different ($P < 0.05$).

three cages per genetic group) at a stocking density of 45 fish.m^{-3} or 67 fish.m^{-2} (600 fish per cage). The experimental units were assigned randomly to the cages. The caged fish were manually fed to satiation with a commercially available floating pellet of 30% protein content (Charoenphokphand Feed Company Ltd.; Saraburi, Thailand), twice daily (0900 and 1700 hours). The water quality (temperature, pH, total ammonia and dissolved oxygen) was monitored twice a month throughout the experiment.

Growth measurement

Measurement was done on a monthly basis on 10% (60 individuals) of the fish from each replicate. The fish were starved for 1 d and anaesthetized before weighing. The fish weight, feed intake and mortality were recorded throughout the experimental period of 303 d (6 July 2009–5 May 2010). When the experiment was terminated, the survivors were enumerated and survival percentages were calculated. The specific growth rate (SGR) and feed conversion ratio (FCR) were calculated using the following Equation 1 and 2:

$$SGR = 100 \times \frac{\text{ln final weight - ln initial weight}}{\text{number of rearing days}} \quad (1)$$

$$FCR = \frac{\text{feed consumed}}{\text{weight gained}} \quad (2)$$

where all weights and the feed consumed were measured in grams.

Carcass quality

Dress-out and fillet percentage

At the end of the experiment, 60 fish from each genetic group were randomly sampled for dress-out and fillet percentage analysis following the procedure of Argue *et al*. (2003). In brief, each fish was deheaded, the viscera were removed followed by weighing of the carcass. Then, the dress-out was calculated and expressed as a percentage of the body weight. The percentage of fillet yield was defined as the meat weight (without skin) divided by the body weight and expressed as a percentage.

Color analysis

Physical and chemical color analyses of the fillet were performed using a colorimeter (HunterLab; Hunter Associates Laboratory Inc.; Reston, VA, USA) and total carotenoids analysis, respectively. The CIE L*a*b* values (L*= white, -L*= black, a*= red, -a*= green, b*= yellow, -b*= blue; Robb, 2001) of each fillet (number of fish = N = 60 fish per genetic group) were measured at three positions (ventral, dorsal and mid-fillet; Figure 1) following Sinnott (2001). Total carotenoids were isolated and analyzed following Yuangsoi *et al*. (2010). The wavelength of maximum absorbance (λmax; wavelength range 350–600 nm) was determined and total carotenoids were calculated using the Beer-Lambert law (Britton, 1995).

Texture analysis

The texture of the fillet samples was analyzed using a Texture Analyser (TA.XTPlus, Stable Micro Systems, Goldaming, UK) equipped with a 2.0 mm diameter stainless steel cylindrical probe. Each fillet (N = 60 fish per species) was analyzed in triplicate at the position of muscle above the lateral line. The conditions for analysis were as follows: the penetration distance was 15 mm and the probe speed during, pre and post penetration was 1.0 mm.s^{-1}. Firmness was measured as the peak compression force (N) during the penetration of the sample.

Proximate analysis

Fillets (4 × 4 × 1 cm) of 12 fish per genetic group were collected for proximate analysis comprising crude protein, fat, ash and fiber
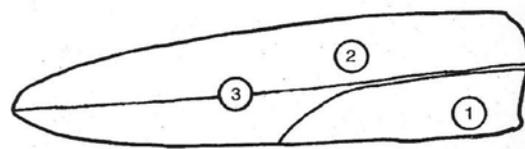

Figure 1 Location of three positions on fillet measured using a colorimeter (Sinnott, 2001).

contents following the protocol of Association of Official Analytical Chemists (1990).

Data analysis

The SGR, FCR, survival rate, carcass quality values and nutrition values were analyzed using analysis of variance. The survival rate was subjected to an arcsine transformation before analysis. Differences of means ($P < 0.05$) among experimental groups were detected using Duncan's multiple range test (Steel and Torrie, 1980).

RESULTS

Survival rate

During the eighth to twelfth weeks of the experiment, the fish were infected by external parasites identified as *Argulus* and monogenes, followed by an infection of bacterial pathogens. The infection was more severe in the hybrid so that the survival rate of this group dropped to 37.83 ± 5.87% compared to 83.5 ± 3.82 and 95.93 ± 1.10% of the parent striped catfish and Asian catfish, respectively.

Growth and feed conversion ratio

The daily SGR of striped catfish, Asian catfish and the hybrid were 1.23 ± 0.02, 1.20 ± 0.02 and 0.60 ± 0.24%, respectively. These SGR values of the striped catfish and Asian catfish were not significantly different ($P > 0.05$) and were significantly higher than that of the hybrid ($P < 0.05$; Table 1). Owing to a concern that the different survival rates may affect the growth performance, the analysis of variance was repeated including the survival rates in the statistical model as a co-variant and the same results were obtained.

The FCR of striped catfish (1.72 ± 0.20), Asian catfish (1.26 ± 0.13) and the hybrid (2.07 ± 0.71) were not significantly different ($P > 0.05$) with the hybrid showing a tendency to have less efficient feed conversion capacity (Table 1). The survival rates of the three genetic groups were significantly different ($P < 0.05$) being highest

in the Asian catfish (95.93 ± 1.10%) followed by those of the striped catfish (83.5 ± 3.82%) and the hybrid (37.83 ± 5.89%) (Table 1).

Dress-out and fillet percentages

The hybrid had the lowest dress-out (37.50%) and fillet percentages (32.15%) when compared with the parental species ($P < 0.05$). Of the parental species, the striped catfish produced a higher dress-out percentage (53.15%) and fillet percentage (43.13%) than the Asian catfish (dress-out percentage = 42.61% and fillet percentage = 35.70%; Table 1).

Color analysis

The L*, a* and b* values of the three genetic groups were significantly different ($P < 0.05$). The brightness (L*) value of the Asian catfish was highest (50.40 ± 1.39), followed by that of the striped catfish (47.38 ± 2.10) and the hybrid (44.81 ± 2.75), whereas the red-green (a*) value and yellow-blue (b*) value of the striped catfish were highest (a* = 4.24 ± 0.69 and b* = 13.35 ± 1.37) followed by that of the hybrid (a* = -0.08 ± 0.66 and b* = 7.49 ± 0.84) and the Asian catfish (a* = -0.87 ± 0.6 and b* = 6.74 ± 1.00; Table 1). Total carotenoids was significantly different ($P < 0.05$) among the three genetic groups as follows; striped catfish (0.68 ± 0.25) > hybrid (0.46 ± 0.34) > Asian catfish (0.19 ± 0.09; Table 1). The total carotenoids pigments made the flesh red and yellow (Nickell and Springate, 2001), which was consistent with the a* and b* values.

Fillet texture

Significant differences in firmness values were observed among the three genetic groups ($P < 0.05$) wherein the hybrid had the least fillet firmness (N = 0.85 ± 0.34). Of the parents, the fillet of the striped catfish (N = 2.84 ± 0.67) was higher than that of the Asian catfish (2.34 ± 0.76) (Table 1).

Nutrient composition

Crude protein, fat, ash and fiber percentage

values are presented in Table 2. The hybrid had higher crude protein and ash and lower lipid contents than those of the parents (striped catfish and Asian catfish). No significant differences in fiber were observed among the three species studied.

DISCUSSION

Survival and growth rate of the hybrid

In this study, the growth and survival rates of the striped catfish × Asian catfish hybrid were significantly lower than those of the parental species while the feed conversion ratios were similar. One of the objectives for hybridization (and cross breeding) is to make use of positive heterosis where the hybrid performs better than the average of the parents (Falconer and Mackay, 1996). However, where the parental species are too genetically diverse, hybridization may break the favorable linkage groups of each parental species and thus compromise the performance of the hybrid (so-called 'out-breeding depression, for example, Edmands *et al*., 2005; McClelland and Naish, 2007). The genetic divergence between striped catfish and Asian catfish based on sequences of 16S rRNA was large (0.041; Na-Nakorn *et al*., 2006) compared to the divergence between striped catfish and other *Pangasius* species (0.030–0.038; Na-Nakorn *et al*., 2006). Therefore, it was surmised that the inferiority of the striped catfish × Asian catfish hybrid may have been caused by out-breeding depression. The growth, survival and FCR of the inter-specific hybrid varied among cross types (Bartley *et al*., 2001) and were better

than both parental species in the channel catfish × blue catfish hybrid (Giudice, 1966; Dunham and Brummett, 1999) and the white bass × striped bass hybrid (Smith, 1988), intermediate for example, in the walking catfish × African catfish hybrid (Na-Nakorn, 2001; Koolboon *et al*., 2014), similar to the parent species for example in the walleye × sauger hybrids (Siegwarth and Summerfelt, 1993) and lower than the parental species with the *Sparus aurata* × *Pagrus pagrus* hybrid (Paspatis *et al*., 1999). The variety in the production performance depends on the genetic structure of the parent fish (Bartley *et al*., 2001; Koolboon *et al*., 2014) and the species used as the maternal source and the genetic-environment interaction (Dunham, 2004).

Dress-out and fillet percentages

The dress-out and fillet percentages of striped catfish and Asian catfish in this study were in the range previously reported for the Pangasiids, for example, 35–39% fillet yield reported for the striped catfish in Thailand and Vietnam (Mongkonpanya *et al*., 1996; Sang *et al*., 2009) and 41–47% fillet yield of the Asian catfish in Thailand (Ratana-arporn *et al*., 2007). The hybrids had lower percentages of dress-out and fillet yields than those of the parental species, and this may be explained by the out-breeding depression mentioned above. The relative processing yields of interspecific hybrids compared to their parental species were varied; for example, being higher than those of parental species for the hybrids between *Catla catla* × *Labeo fimbriatus* and channel catfish × blue catfish (Basavaraju *et al*.,

Table 2 Nutrition values of *Pangasianodon hypophthalmus*, hybrid and *Pangasius bocourti*.

Nutrition value (%)	Species		
	P. hypophthalmus	Hybrid	*P. bocourti*
Crude protein	69.43 ± 6.57 [b]	74.74 ± 2.58 [a]	68.46 ± 5.24 [b]
Lipid	24.11 ± 5.20 [a]	15.64 ± 1.63 [b]	25.96 ± 6.71 [a]
Ash	5.01 ± 0.61 [b]	5.52 ± 0.47 [a]	4.18 ± 0.42 [c]
Fiber	0.18 ± 0.09 [a]	0.16 ± 0.05 [a]	0.13 ± 0.03 [a]

Means with different letters as superscripts are significantly different ($P < 0.05$).

1995; Argue *et al*., 2003), inferior to the parents as reported for the dress-out percentage of channel catfish and blue hybrid catfish (Dunham *et al*., 1983) and not different from the parents as shown for dress-out and fillet percentages of striped catfish × Mekong giant catfish (*Pangasianodon gigas*) hybrids (Mongkonpanya *et al*., 1996) and Thai walking catfish (*Clarias macrocephalus*) × African catfish (*C. gariepinus*) according to Koolboon *et al*. (2014). The large variability in the processing yield could have been affected by the strain used for hybrid production, or the sex, age and size and whether the processing method was mechanical or manual (Ammerman, 1985; Argue *et al*., 2003). However, Koolboon *et al*. (2014), based on a well-designed experiment, reported that no strain effects were revealed on the fillet yield and dress-out percentage when using three strains of Thai female walking catfish hybridized with three strains of male African catfish male.

Color of fillet

Fillet color is an important characteristic in the premium quality specification of white fish fillets (Alaska Seafood Marketing Institute, 2014). Yellow fillets were graded as poor quality with a low price compared to white fillets (Sørensen, 2005; Alaska Seafood Marketing Institute, 2014). Generally, the flesh of Thai striped catfish is yellow compared with Asian catfish and it showed the highest yellow value (b* = 13.35) in this study. Hybrid fillets showed an intermediate value of yellow and their flesh was less white than Asian catfish (Table 1). The whiteness (L*) and yellow value of white fish species such as cod and halibut range from 43.7 to 79.3 and -3.0 to 8.5, respectively (Bjørnevik *et al*., 2003; Foss *et al*., 2009; Bjørnevik and Solbakken, 2010). Following these criteria, the hybrid could be classified as a white fish. However, its flesh color was of inferior quality compared to that of the Asian catfish. The range in the color value is wide because there are many factors influencing flesh color, including not only the genetic group (species or strain),

but also culture conditions (dietary composition, feeding regime, water quality, fish activity) and the processing method involving the killing method, handling and transporting (Sinnott, 2001; Bjørnevik *et al*., 2003; Sørensen, 2005; Foss *et al*., 2009; Bjørnevik and Solbakken, 2010). Flesh color improvement cannot be achieved using only a genetic approach.

Fillet texture and nutritional composition

Fillet texture is an important parameter of farmed fish quality (Sinnott, 2001). Consumers generally prefer a firm and elastic fillet texture because soft fish flesh is usually too fragile for processing and cooking (Bahuaud *et al*., 2010). In the present study, the firmness value of the hybrid was lowest compared to that of the parental species (striped catfish = 2.84 N, Asian catfish = 2.34 N, and hybrid = 0.85 N). The firmness of the fillet reflects a high density and narrow diameter of the muscle fiber (Hurling *et al*., 1996, Periago *et al*., 2005) which potentially relate to a high growth rate (Rasmussen and Ostenfeld, 2000; Periago *et al*., 2005). In this study, the low growth rate of the hybrid may have resulted in the low density of muscle fiber compared to that of the striped catfish and Asian catfish and thus led to less firmness in its fillet. The crude protein and lipid contents of striped catfish and Asian catfish were similar to those of previous studies, ranging from 59.86 to 67% and from 20.5 to 31.3% (dry matter), respectively (Puwastien *et al*., 1999, Thammapat *et al*., 2010). The crude protein content of the hybrid in this study (74.74%) was higher than in a previous report (67%) while the lipid amount was equal (Tulyapongrak, 2008). When compared to the parental species, the hybrid had a higher amount of crude protein than that of the parental species, while the lipid content was lower ($P <$ 0.05). A low lipid deposition and high protein level of the hybrid may reflect different metabolic patterns and hence these deserve further study.

CONCLUSION AND

RECOMMENDATIONS

The hybrid of the striped catfish and Asian catfish showed inferior performance (growth, survival and carcass quality) compared to the parental species when reared in a standing water cage. Although the performance of the interspecific hybrid also depends on the strains of the parental species (Koolboon *et al.*, 2014), the effect of strains was small and may not be worth re-evaluation using different parental strains. However, the inferior performance of the hybrid caused by out-breeding depression may be restored by back-crossing (Edmands *et al.*, 2005), providing that the hybrid is not fully sterile. Rather, development of white-fleshed fish aquaculture in Thailand should focus on the improvement of striped catfish or Asian catfish via genetic improvement, feed, aquaculture conditions and hatchery production improvement.

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