Analysis of growth and nutritional values of three generations of Asian redtail catfish (*Hemibagrus nemurus*)

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Abstract. The Asian redtail catfish (*Hemibagrus nemurus*) is a popular aquaculture fish species that contains essential nutrients for health. This research was carried out to evaluate the growth and nutritional values of the domesticated fish from 3 generations. 3 generation brood-stocks were artificially spawned using GnRH-analog hormone injection to produce fish larvae. The larvae were reared in the rectangular tank to reach the fingerling phase over two months. The fingerlings (with a length of 7.67±0.06 cm and a weight of 7.12±0.23 g) were cultured in semi-permanent ponds (160 cm x 80 cm x 100 cm), at a density of 100 fish per pond over 180 days and fed twice a day using commercial diets. The growth performances (weight gain, specific growth rate) of the first (G1), second (G2), and third generations (G3) showed no significant differences. The coefficient of variation (CV) of G2 was 26.61±11.39% and it was higher than that of G1 (18.26±0.65%) and G3 (14.71±2.45%). The factor condition (K) ranged from 0.81±0.02 to 1.02±0.5. The length-weight relationship showed that the growth pattern was allometric negative (<3), indicating a faster increase in length than in weight. This study revealed that female fish grew more than males. It can be suggested that a feminization program could be considered The Asian redtail catfish provided essential nutritional values, as contained by striped catfish, tilapia, and African catfish. The edible portion of *H. nemurus* was larger compared to that of striped catfish, tilapia, and African catfish. Thus, this species is recommended to be developed as a potential species for aquaculture.
Key Words: domesticated fish, edible portion, nutrition, specific growth rate.

Introduction. The Asian redtail catfish, *Hemibagrus nemurus* (Valenciennes, 1840), is one of the economically important riverine catfish in Indonesia and southeastern Asian countries. The fish has a high quality flesh, containing valuable sources of protein and omega-3 fatty acids (Mesomya et al 2002; Abdi 2014). The market price of this species is higher compared with other freshwater fish such as African catfish (*Clarias gariepinus*), striped catfish (*Pangasius hypophthalmus*), and Nile tilapia (*Tilapia niloticus*) in Indonesia, Malaysia, and Thailand (Rahmah et al 2014; Handoyo et al 2010). However, the supply of fish mainly relies on the wild stock and captive rearing of seeds as intensive hatchery production is not well established (Adebiyi et al 2013; Gustiano et al 2018). Therefore, many studies were conducted to support hatchery production including the investigation of reproductive performance (Adebiyi et al 2011; Suharman & Aryani 2015), feeding management (Thongprajukaew & Rodjaroen 2017), hormonal induced spawning (Adebiyi et al 2013; Aryani & Suharman 2016) and larval rearing (Kamarudin et al 2011; Adebiyi et al 2013).

The Research Institute for Freshwater Aquaculture and Fisheries Extension (RIFAFE), Bogor, Indonesia conducted experiments to domesticate potential brood-stocks from different locations including Cirata reservoir, Cisadane, and Serayu rivers. The results revealed that bio-reproduction and growth of fish collected from Cirata reservoir have a good performance (Subagja et al 2015). Therefore, to continue the success of domestication programs for this species, research was developed based on fish collected from Cirata population to produce the next brood-stock generations. Providing high-quality fish generations through a domestication program is necessary to improve fish production. Thus, this research aims to evaluate the growth, nutritional and economical values of fish produced from three different generations.

Material and Method

Growth. This research was carried out from November 2017 to April 2018 at pond cultures of the Research Station for Freshwater Fisheries Germplasm, Bogor, Indonesia. Experimental fish were produced from the domestication program of Cirata population. 3 broodstocks from different generations (G1, G2, and G3) were artificially spawned using GnRH-analog hormone injection. After eggs were incubated in the tanks, they hatched within approximately 24 hours. Fish larvae were reared in rectangular tanks with aeration to ensure dissolved oxygen levels maintained throughout the tanks. The first feeding was initiated after 4 days using *Artemia* spp. for 14 days and continued with commercial feed to reach the fingerling phase for 2 months. Subsequently, the fingerlings (length: 7.67±0.06 cm, weight: 7.12±0.23 g) were stocked in 3 replicates of semi-permanent ponds (160 cm x 80 cm x 100 cm) with a stocking density of 100 fish per pond. During the study, fish were fed twice a day using commercial diets (34% crude protein), 5% weight of biomass per day. Fish growth was measured every 30 days over the 180 days of the experiment. The growth parameters were calculated, including specific growth rate (SGR), coefficient of variation (CV) for body weight (CVbw) and fork length (CVfl), the length-weight relationship (W), standard weight (Ws) predicted by the length-weight relationship formula and condition factor (K).

$$SGR = \frac{lnWt - lnWi}{t} x\ 100$$

Where: wt - final weight; wi - initial weight; t - the cultured period in a day.

$CVbw = \frac{SD\ bw}{BW} x\ 100$ and $CVfl = \frac{SD\ fl}{FL} x\ 100$

Where: SD - standard deviation for body weight/length; bw - average body weight (g); fl - average fork length (cm).

$W={}_aL^b$

Where: a - the intercept of the regression curve; b - the regression coefficient.

$K=WL^{-3}$ x 100

Where: W - weight (g); L - length (cm); the value of 100 is used to ensure that the K value is close to unity.

Nutritional values. Proximate analysis, fatty acid contents, and edible portions were investigated to determine the nutritional values of fish. The proximate analysis was performed at the fish nutrition laboratory of RIFAFE to calculate the percentage of crude protein, crude fat, moisture, and ash in fish fillets. The protocol for proximate analysis followed the Indonesian Nasional Standard (SNI 01-2891-1992) for proximate determination (BSN 1992). Fatty acids analysis was conducted at the Biochemistry Laboratory of FMIPA IPB University to determine SFA (Saturated Fatty Acids), MUFA (Monounsaturated Fatty Acids), and PUFA (Polyunsaturated Fatty Acids). The standard protocol used for fatty acids analysis followed AOAC (2012). To evaluate flesh proportion, the carcass quality was analyzed to calculate the edible portion such as flesh yield and dressing percentage. Flesh yield was calculated based on the weight of flesh compared to total weight represented by the fillet weight, while the dressing percentage represents an inedible part of the fish, such as head, organs, spines, and fins. All analyses were conducted on three different fish.

Statistical analysis. The Duncan test was conducted to evaluate fish growth data. One-way-ANOVA was performed to compare the performance of three generations of fish. Statistical analysis was performed using SPSS 16.0 software and a significance level of $P<0.05$ was applied.

Results and Discussion. The growth of G2 presented a greater performance (final weight of 90.65±0.56 g) compared with other generations (G1 with 86.66±4.61 g and G3 with 84.11±2.26 g) (Table 1). These conditions were supported by the SGR values of G1, G2, and G3, with 1.39±0.03%, 1.41±0.02%, and 1.38±0.01%, respectively. The weight of G2 was higher with 4.92% and 8.31% compared with G1 and G3, respectively. Similarly, the length of G2 was also higher with 6.99% compared to that of G1, and 6.13% compared to that of G3. However, there were no significant differences among generations ($P>0.05$).

Table 1

The growth performance (length, weight, and specific growth rate) of the Asian redtail catfish (*Hemibagrus nemurus*) from three generations

Generations	*Phase*	*Length (cm)*	*SGR_{FL} (%)*	*Weight (g)*	*SGR_{BW} (%)*
	Initial	7.67±0.09		7.12±0.25	
G1	Final	16.39±0.35	0.42±0.01	86.66±4.61	1.39±0.03
	ΔGrowth	8.73±0.29		79.55±4.52	
	Initial	7.70±0.06		7.19±0.22	
G2	Final	17.03±0.76	0.44±0.02	90.65±0.56	1.41±0.02
	ΔGrowth	9.34±0.70		83.46±0.69	
	Initial	7.64±0.04		7.05±0.23	
G3	Final	16.43±0.12	0.43±0.00	84.11±2.26	1.38±0.01
	ΔGrowth	8.80±0.09		77.06±2.07	

Note: ΔGrowth – weight/length gain; SGR_{FL} – specific growth rate for length; SGR_{BW} – specific growth rate for weight.

Comparing males and females of each generation within similar ages, *H. nemurus* females presented better performance both in length and weight compared to males (Table 2). This indicates that the females could be more profitable if used in aquaculture, as they can impact feeding efficiency, culture period, and production input.

Table 2

Growth comparison of Asian redtail catfish (*Hemibagrus nemurus*) males and females from three generations

Generation	*Length(cm)*		*Weight (g)*	
	♂	♀	♂	♀
G1	16.52±1.06	16.67±0.76	83.01±13.09	91.59±12.93
G2	16.50±0.20	16.70±1.11	89.18±0.91	94.71±21.16
G3	16.43±0.12	16.83±0.29	85.56±4.44	88.20±2.54

The population heterogeneity of the Asian redtail catfish can be predicted based on the coefficient of variation (CV) values. The G2 fish had the greatest CV value (26.61±11.39%), followed by G1 (18.26±0.65%) and G3 (14.71±2.45%) (Table 3). A higher CV value indicates a higher diversity level of fish that can provide a beneficial impact on fish selection in the population. The CV value declined for the G3 fish, indicating the increase of offspring homogeneity. This can be used as an indicator in evaluating fish breeding programs.

Table 3
Coefficient of variation (CV) of the Asian redtail catfish (*Hemibagrus nemurus*) from three generations

Generations	*Parameter*	*CV (%)*
G1	Length (cm)	6.67±0.04
	Weight (g)	18.26±0.65
G2	Length (cm)	7.77±3.05
	Weight (g)	26.61±11.39
G3	Length (cm)	4.89±0.43
	Weight (g)	14.71±2.45

The length-weight relationship of the Asian redtail catfish indicated that the growth of fish was allometric negative. The allometric parameter (b) value of G2 fish was the greatest, followed by G1 and G3. The different b value of G2 was 4.07%, higher with 8.08% than that of G1 and G3, respectively. This suggested that G2 performed better in length and body weight. The coefficients of determination (R) of G1, G2, and G3 were 0.92, 0.76, and 0.94, respectively (Figures 1, 2, and 3). The high R values illustrated that length-weight relationships were influenced by internal factors rather than external conditions. The condition factor (K) values of G1 and G2 were 1.02±0.05 and 1±0.08, respectively, while G3 presented a lower K value, of 0.81±0.02 (Table 4).

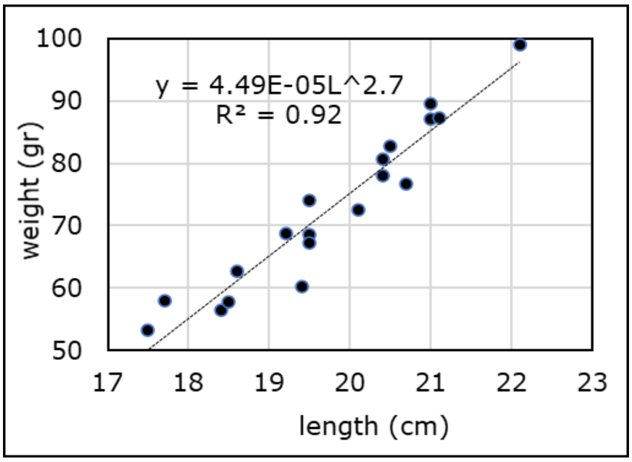

Figure 1. Length-weight relationship of Redtail catfish (*Hemibagrus nemurus*) from the first generation.

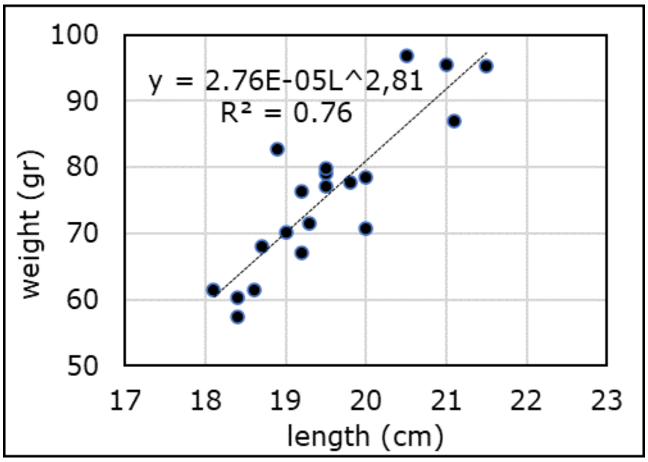

Figure 2: Length-weight relationship of Redtail catfish (*Hemibagrus nemurus*) from the second generation.

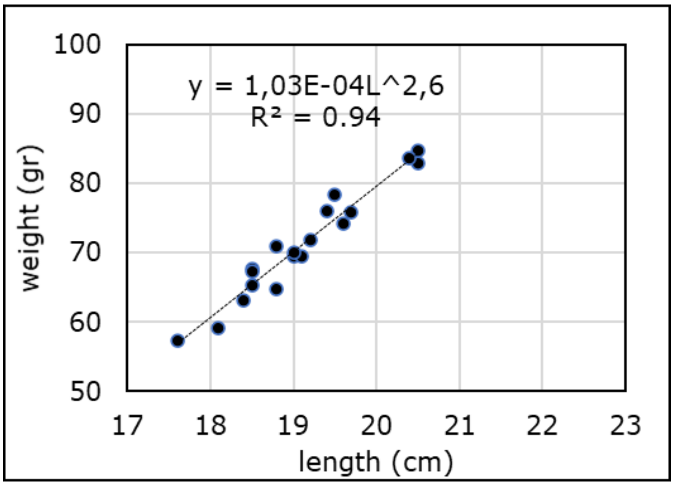

Figure 3: Length-weight relationship of Redtail catfish (*Hemibagrus nemurus*) from the third generation.

Table 4
Comparison of predicted standard weight (Ws) and condition factor of three generations of *Hemibagrus nemurus*

Parameter	*Generation*		
	G1	*G2*	*G3*
Length (mm)			
Minimum (mm)	175	181	176
Maximum (mm)	221	215	205
Average (mm)	197.42±12.36	195.1±9.48	191.11±7.99
Weight (g)			
Minimum (g)	53.29	57.4	57.26
Maximum (g)	99.01	96.9	84.69
Average (g)	72.66±12.92	75.67±11.74	71.14±7.8
Predicted standard weight (g)			
Minimum (g)	51.1	60.95	70.99
Maximum (g)	95.96	98.86	105.54
Average (g)	71.36±11.92	75.69±10.55	88.24±9.66
Condition factor			
Minimum	0.89	0.88	0.77
Maximum	1.08	1.12	0.84
Average	1.02±0.05	1±0.08	0.81±0.02

Comparing predicted weight and observed weight of *H. nemurus* showed that the value of predicted weight for G1 (71.36±11.92 g) and G2 (75.69±10.55 g) were relatively similar to the observed weight of G1 (72.66±12.92 g) and G2 (75.67±11.74 g). However, the predicted weight of G3 (88.24±9.66 g) was an overprediction compared with the observed weight of G3 (71.14±7.8 g).

The edible portion of *H. nemurus* was estimated based on the comparison of flesh yield and dressing percentage. The flesh yield portion of 3 generations of *H. nemurus* ranged from 44.39% to 47.17% for males and 47.11 to 48.64% for females (Figures 4, 5, and 6). G2 had the greatest flesh yield for both males and females. In G1, G2, and G3, the female edible portion was 6.13%, 2.38%, and 3.03% higher than the male edible portion, respectively. Thus, females likely have more economic value than males.

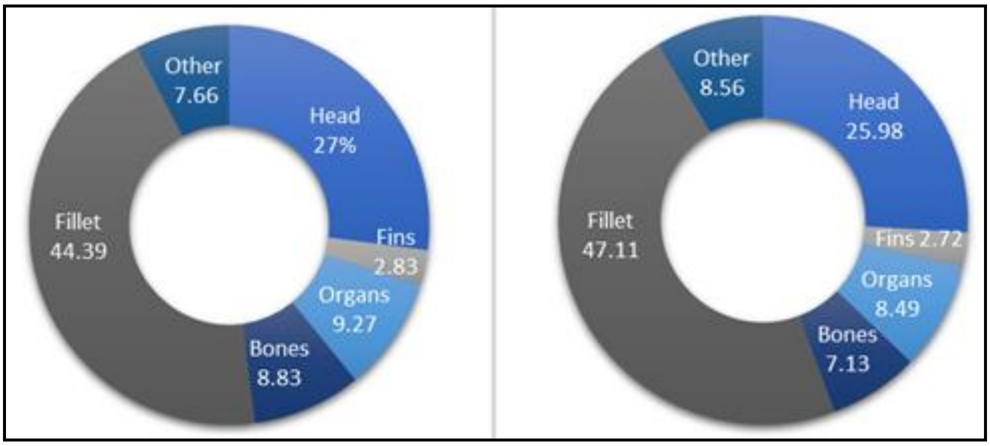

Figure 4. The edible portion (%) of the first generation of the Asian redtail catfish (*Hemibagrus nemurus*) males (left) and females (right).

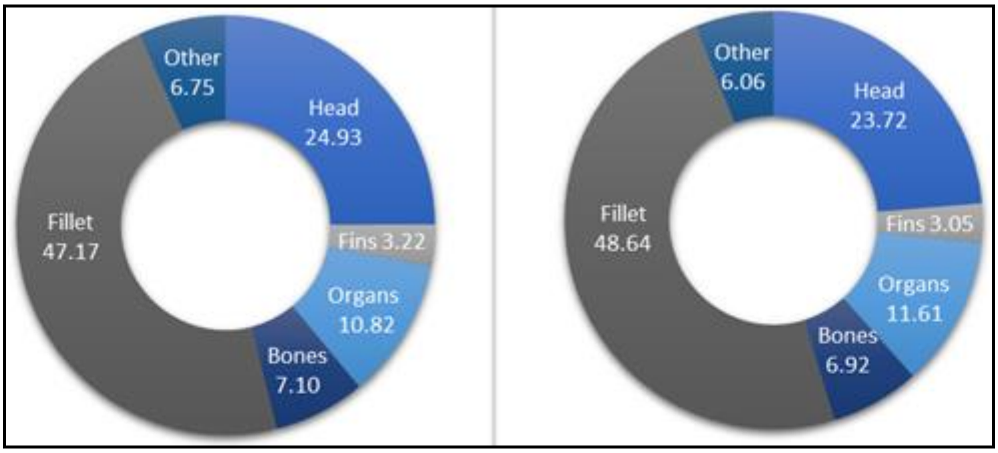

Figure 5. The edible portion (%) of the second generation of the Asian redtail catfish (*Hemibagrus nemurus*) males (left) and females (right).

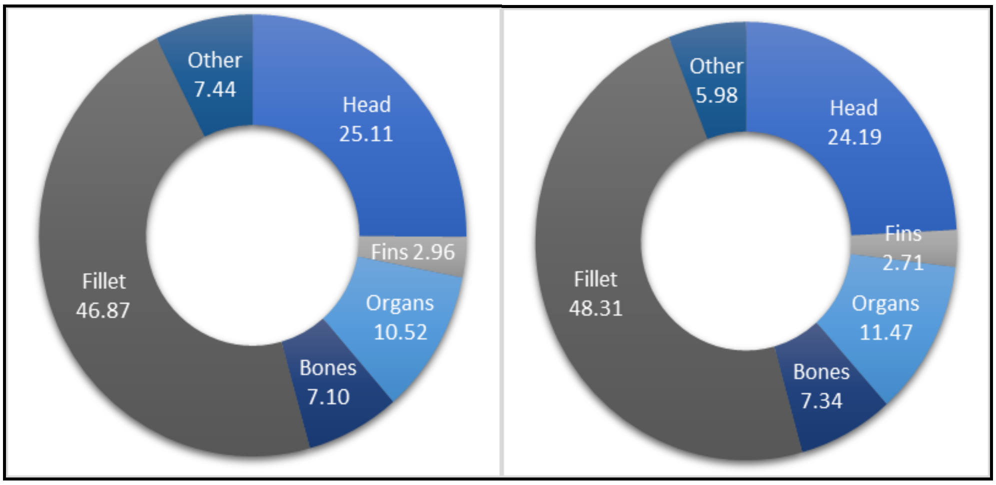

Figure 6. The edible portion (%) of the third generation of the Asian redtail catfish (*Hemibagrus nemurus*) males (left) and females (right).

Based on nutritional values, *H. nemurus* contained high levels of crude protein and essential fatty acids such as laurate, myristate, palmitate, stearic, oleic, linoleic, linolenic acid, EPA, and DHA (Tables 5 and 6). The fish flesh presented high-level nutritional values and it provided large proportions of the fillet. The G2 fish fillet proportions were 47.17% and 48.64%, for males and females, respectively, higher compared to striped catfish, tilapia, and African catfish (Table 5). *H. nemurus* fillet contained lower moisture than other cultured fish. The low moisture of G2 fish indicated a denser flesh texture. The crude fat content of G2 was the greatest. The G2 fish also contained essential fatty acids (Table 6).

Table 5

Nutritional values of the Asian redtail catfish (*Hemibagrus nemurus*), striped catfish (*Pangasius hypophthalmus*), African catfish (*Clarias gariepinus*), and BEST tilapia (*Tilapia niloticus*)

Parameter	*Fish species*			
	Asian redtail catfish (G2)	*Striped catfish**	*Tilapia BEST***	*African catfish ****
Crude protein (% of dry weight)	78.01	84.99	79.53	55.33
Crude fat (%)	15.17	2.03	10.71	2.75
Moisture (%)	73.81	82.27	77.71	80.10
Fillet (%)	47.08	42.29	35.53	40.01

Note: * - Alhana (2011); ** - Kusmini et al (2015); *** - Yuarni et al (2015); Erlangga (2009); BEST tilapia - Bogor enhanced strain of Nile tilapia.

Table 6

Fatty acids of the Asian redtail catfish (*Hemibagrus nemurus*), 3 different strains of striped catfish (*Pangasius hypophthalmus*), GIFT tilapia (*Tilapia niloticus*), and African catfish (*Clarias gariepinus*)

Fatty acid		*Concentration (%)*					
		Asian red tail catfish (G2)	*Jambi striped catfish**	*Karawang striped catfish**	*Imported striped catfish**	*GIFT tilapia***	*African catfish****
SFA (Saturated Fatty Acids)							
Laurate	C12:0	7.52	0.82	0.10	0.08	3.50	1.87
Myristate	C14:0	1.28	4.05	3.10	2.30	4.02	3.22
Palmitate	C16:0	33.21	24.05	20.97	16.74	25.46	25.06
Stearate	C18:0	25.86	6.48	5.87	4.11	6.19	1.94
MUFA (Monounsaturated Fatty Acids)							
Oleate	C18:1	28.74	27.55	20.83	15.23	26.51	56.91
PUFA (Polyunsaturated Fatty Acids)							
Linoleic	C18:2	4.56	7.63	9.31	10.71	2.68	5.69
Linolenic	C18:3	1.28	0.41	0.87	1.44	1.70	1.05
EPA	C20:5	1.06	0.25	0.54	0.95	1.10	1.29
DHA	C22:6	0.88	0.76	1.55	2.72	5.34	0.63

Note: * - Syukur (2014); ** - Miranda (2017); *** - Salasah & Nilawati (2016). GIFT tilapia - genetically Improved farmed tilapia.

Fish domestication programs aim to produce fish with better performance compared with fish populations in the wild to improve aquaculture benefits (Lorenzen et al 2012). The increasing growth rate of selected fish is an essential indicator used for the next breeding programs in creating potential broodstocks for aquaculture development. The growth of G2 was higher than that of the previous generation. This indicated that the domestication program likely succeeded in creating beneficial attributes for improving the economic value of the targeted aquaculture species. The daily growth rate of G2 was 1.41±0.02% and it was higher with 1.44% and 2.17% compared with the daily growth rate of G1 and G3, respectively. A previous study reported that the daily growth rate of the Asian redtail catfish reared in cages in earth ponds were 1.09±0.1% and 1.19±0.07% for 2 different locations (Subagja et al 2018). The excellent growth of the G2 fish provided evidence that genetic improvement could have occurred from the previous generations. However, the decreasing growth of the G3 fish likely indicated a decline in genetic variation.

Increasing and reducing the growth of domesticated fish in different generations illustrate that genetic gain for improved fish growth can be selected for the next breeding program (Solberg et al 2013).

Phenotype diversity in fish can be observed from the body length or weight. The changes in fish weight are affected by feed intake and energy allocation used for growth and reproduction, which cause fish of similar lengths to have different weights (Meretsky et al 2000). The CV values of *H. nemurus* were commonly in line with the CV values as reported by Gjedrem (2005), ranging from 17 to 29%. The highest CV was found for G2 fish (26.61±11.39%). According to Tave (1993), fish populations with a CV value higher than 25% are more successful in a selection program as compared with other populations (with lower CV values). The observations of length-weight relationships in fish are useful for predicting fish growth patterns (Jobling 2002). This research revealed that the growth of *H. nemurus* was allometric negative (b value lower than 3). This indicates that the length increased more than the weight and the fish tended to present a more slender shape (Blackwell et al 2000). The length-weight relationship needs to be considered in the selection of aquaculture commodities to meet the trends of seafood products in the market.

The value of the fish condition factor ranged from 0.84 to 1.12. K value predicts the physical condition of fish (Froese 2006). Barnham & Baxter (1998) reported that a K value of 1 indicates the poor condition of fish, being long and thin, while a K value of 1.2 indicates a moderate condition, the fish being acceptably proportioned. K values variation in fish is mainly related to age, sex, growth, maturation stage, feed, and environmental conditions (Battacharya & Banik 2012; Jega et al 2017). K commonly increases with optimum diets fish growth (Bassey & Ajah 2010). According to Effendie (2002), K is an indicator to predict the physical capacity of fish for survival and reproduction. K is also an essential parameter in aquaculture management systems as it can predict specific conditions occurred in cultured fish (Araneda et al 2008).

The fish edible portion was evaluated to determine the proportion of fish utilized for raw materials in the processing industry (Ljubojević et al 2012). The edible portion of the Asian redtail catfish was higher compared with striped catfish, Nile tilapia, and African catfish. Fish species, sex, age, size, diet, and culture systems are the main factors that affect flesh performance (Argue et al 2003; Ljubojević et al 2012). The edible portions of the Asian redtail catfish females were higher than those of males. This information indicated that females likely provide more economic value than males. Thus, it can be suggested that a feminization program can be implemented to produce female fingerlings used in monoculture aquaculture ponds to improve profits.

The nutritional composition of fish meat is essential in providing information about quality and health of food (Foran et al 2005), postharvest processing (Campbell & Ward 2004), and requirements for food regulations and commercial specifications (Murray & Burt 2001). The nutritional composition of the Asian redtail catfish from G2 was different compared with that of striped catfish, African catfish, and Nile tilapia. Petricorena (2015) reported that the nutritional composition of fish varies greatly among species, age, sex, environment, and season. The G2 fish presented a higher level of fat content (15.17%) compared with other freshwater species (Table 5). Venugopal (2005) categorized fish based on fat content into 3 groups: low fat (<3%), moderate fat (3-5%), and high fat (>7%). G2 fish had high levels of fatty acids, including omega 3 (EPA and DHA), SFA, MUFA, and PUFA that were also found in striped catfish, Nile tilapia, and African catfish (Table 6). A good fatty acid composition in fish is a basic requirement in improving dietary formulation, processing, and marketing of aquaculture species (Jabeen et al 2011). Nutritional values in fish, such as EPA and DHA can be improved based on raw material used in the formulated feed (Watters 2012). EPA and DHA contents in fish are essential for seafood and pharmaceutical industries as they can prevent cardiovascular disease, obesity, and other health issues (Watters et al 2012; Diana 2012). However, excessive consumption of DHA has negative impacts on kidneys due to the inhibition of enzyme production for controlling kidney functions (Almatsier 2002). Thus, it is necessary to publish nutritional specifications in commercial fish products. In addition, EPA also plays an important role in preventing degenerative diseases in both infants and adults. In the pregnancy period, EPA is involved in the formation of blood vessels and fetal heart cells (Duthie & Barlow 1992). In adults, EPA is important for blood nourishment, blood vessels, and heart function (Farrell 1998).

Conclusions. The second generation of the Asian redtail catfish performed better in terms of growth and weight than the G1 and G3 fish. The growth of G2 was higher with 1.44% to 2.17% compared with the other generations, indicating the G2 could present a greater economic value. This study revealed that the growth of female fish was higher than that of the males. Thus, it can be suggested that a feminization program can be suggested in the next research to improve business profit in aquaculture. The Asian redtail catfish also provides high nutritional values, as striped catfish, Nile tilapia, and African catfish. The edible portion of *H. nemurus* was the greatest compared with striped catfish, Nile tilapia, and African catfish. Therefore, this species is recommended to be developed as a potential species for aquaculture.

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