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Compensatory growth response with switching dietary protein levels in common lowland frog, *Rana rugulosa*

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Abstract The results showed outstanding highest growth performance and feed utilization at the end of the trial, especially yield and economic value for T5 ($P<0.05$). The survival rate of T3 was the lowest (82.50%) while the other groups were in the range of 92.50 – 100.00% ($P<0.05$). The carcass composition in terms of edible flesh and flesh quality in terms of percentage of protein was highest in T1 and T5 which were 31.91 – 32.57 % and 73.50 – 73.83 %, respectively ($P<0.05$). Therefore, feeding frogs for the first month, catfish feed for the second month, and frog feed for the third month revealed suitable feeding regime by the response on compensation, promoting growth performance and feed utilization, and provided the highest yield lowest feed cost.

Keywords: Common lowland frog, Compensatory growth, Protein, Switching level

Introduction

For aquaculture, the critical cost for aquatic animal production is feed. It indicated that production profit is about 30 – 70% of total cost from feed (Halver and Hardy, 2002; Das *et al*., 2012). The price of feed depends on protein content, high protein feeds have higher cost. Frogs are carnivorous animals which require high protein diet, thus, their feeds are at high price. Most herbivorous and omnivorous fishes require a dietary crude protein with 25 to 35 percent, while carnivorous species may require 40 to 50 percent crude protein depending on the species (Wilson, 2002). The price for carnivorous animals with high protein depends on the protein source such as fish meal, soybean meal, protein hydrolysate, and others. Mish meal is the highest in price for protein source in feedstuff.

The common lowland frog is a carnivorous species that require high protein feed. The protein requirement from tadpole to adult frog is about 30 – 45% (Somsueb and Boonyaratpalin, 2002). The high protein requirements makes the feed price and production cost high. For this reason, frogs may be

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fed with low protein feed, which has lower than the price of frog feed yet provides average growth performance at reduced production cost. A feeding regime is needed to economically manage the balanced growth and cost. The feeding regime by compensatory growth (CG) could be the key to handling the frog production cost problem. The high feed cost problem found in many economic aquatic animals were solved with the compensation response such as in red tilapia (Klahan *et al*., 2020), Nile tilapia (Rodjaroen *et al*., 2020), and juvenile *Oreochromis mossambicus* (Gabriel *et al*., 2018).

The compensatory growth gives more rapid growth than average following the growth - painful conditions (Álvarez, 2011). The CG animal potentially catches up in size with non-stunted animals and achieves approximately the same size for age as those contemporaries continuously given high nutrient diet (Klahan *et al.*, 2020). After starvation, the compensatory response mechanism is hyperphagia (Álvarez, 2011). The study on compensatory growth using food deprivation to induce growth depression can be classified into several terms (Das *et al*., 2020). The study include deprivation, total or partial—starvation, and refeeding in a long and short period. There has been a single period of deprivation, or periods of deprivation and refeeding in alternated cycles. They are even given under nutrient requirement feeding in the alternate cycle for feeding regime, crowding, stress, ontogenetic changes, seasonal variation, sexual maturation and reproduction (Das *et al*., 2012).

CG has been found to be effective in many species, especially in fish, amphibians (Hector *et al*., 2011; Vonesh and Bolker, 2005) and Chinese three-keeled pond turtles (Xu *et al*., 2014). The compensatory growth affected positively on growth, survival, digestive enzyme activities, and carcass quality represented in Juvenile Tongue Sole (*Cynoglossus semilaevis*) (Ziheng *et al*., 2017), milkfish (Lingam *et al*. (2019), *P. bocourti* (Jiwyam, 2010), Thai pangas (Amin *et al*., 2005). Reduced production costs by compensatory response was observed in Nile tilapia (*Oreochromis niloticus*) (Rodjaroen *et al*., 2020), wild brown trout (Näslund *et al*., 2015), Amazon fish (Urbinati *et al*., 2014), and Oreochromis mossambicus juveniles (Gabriel *et al*., 2018). Hector *et al*. (2011) studied brown tree frog tadpoles and found that nutritional restriction affected the developmental rate and resulted in 'over-compensation growth in an amphibian. The tadpole stage studied by Capellán and Nicieza (2007) suggested that sub maximum and compensatory growth could have evolved to minimize the overall growth/mortality costs in environments with high spatiotemporal variation in predation intensity.

The amphibians are susceptible to environmental factors during development, such as pond drying and flood, food abundance, and the densities of conspecifics and predators (Hector *et al*., 2011). This environment affects the adaptability of amphibians is effortless to respond to compensatory growth. The study in amphibians indicated that the compensation supports the prevalence of compensatory growth adapted to ephemeral environments (Hector *et al*., 2011). This study aimed to solve the feed cost problem in frog production by using the feeding regime that responds to the compensatory growth economically effectively without negative feedback on the growth and health of frogs.

Materials and methods

Frog preparation

Exactly 500 common lowland frogs (*Rana rugulosa* Weigman) at 45 days old with an initial mean weight of 12.80–12.95 g/frog from a private farm in Phetchaburi Province were acclimated in fiber tank size 500 l capacity for one week and fed with 35 % protein diet before starting the experiment.

Experimental diet

Commercial floating pellets feed for frog, catfish, and herbivorous was used as feed trials containing 35, 25, and 15.5 % protein. The proximate composition of practice diets was determined using Kjeldahl method for crude protein, Soxhlet method for lipid, the Detergent method for crude fiber, Oven drying method for moisture, and determination of ash using muffle furnace (A.O.A.C., 2000).

Experimental procedure

The current experiment was designed as completely randomized design (CRD) were divided into 5 five treatments were randomly assigned to triplicate groups of frogs; the initial weight ranged 12.80 – 12.95 g and stocked into a cement tank with a dimension of 1.2 m at a density of 30 frogs per tank. They were divided into five treatments with three replications following the feed types. Frog fed with frog feed for all three months (T1, control), frog feed for the first month, catfish feed for the second month, and herbivorous feed for the third month (T2), frog feed for the first month, herbivorous feed a second month, and catfish feed for the third month (T3), frog feed for the first month, herbivorous feed second month and frog feed for the third month (T4), frog feed for the first month, catfish feed second month and frog feed for the third month (T5). All groups of frogs were fed with the trial diet to satiation thrice daily for 90 days. In addition, water was changed at 100% for all the culture systems every three days throughout the study.

Enzyme extraction

Specimens (pancreas and intestines) of the frog from each treatment (n = 30) were weight and collected to extract the crude enzyme. Pancrease and intestines were separated weight and homogenized tissue/mL (w/v) in 50 mM, Tris – HCL buffer pH 7.5 by using a tissue homogenizer. The resulting preparation was centrifuged at 15,000 g for 20 min at 4 oC The supernatant was kept at -20 ℃ for further serine protease activity analysis (Gimenez *et al.*, 1999).

Enzyme activity analysis

The protease activity of enzyme crude extract was demonstrated through a nonspecific protease activity assay following the method of Bezerra *et al.*, 2005 with slight modification. A substrate, 2% (w/v) azocazien (500 ml; Sigma) in 0.2 M Tris–HCl, pH 9 was mixed and incubated with 20 µl enzyme crude extract for 60 min at 30 oC. The reaction was stopped by adding 500 µl of 20% trichloroacetic acid (TCA). The reaction was centrifuged at 15,000 g for 10 min at 4 ℃. The supernatant (1 mL) was added to 0.1 M NaOH (1 mL) in a test tube and the absorbance of this mixture was measured in a spectrophotometer at 440 nm against a blank similarly prepared except enzyme crude extract. One unit (U) of enzymatic activity was defined as the amount of enzyme release of hydrolyzing azocasein to produce a 0.001 change in absorbance per minute. Protease activity was expressed in units/ml while specific enzyme activity was expressed as units/min/mg protein.

The protein content in enzyme crude extracted was estimated according to Lowry's method (Lowry *et al.*, 1951) using bovine serum albumin (BSA) as the standard.

Analytical methods

The mortality was recorded daily, and frogs in each cement tank were counted monthly and weighed during the experiment. The growth rate was monitored to determine the initial weight (IW), final weight (FW), weighed gain (WG), specific growth rate (SGR.), average daily gain (ADG.), survival rate (SR), feed intake (FI), feed conversion ratio (FCR). Protein efficiency ratio (PER) was calculated according to Castell and Tiews (1980). In the second and third months, three frogs from each replication were collected pancreas and intestine to determine the serine protease activity, according to Bezerra *et al.* (2005). At the end of the experiment, ten frogs from each replication (n = 30 frogs/treatment) were analyzed for the carcass composition and the final-body proximate composition the A.O.A.C. (2002) method.

Statistical analysis

Data obtained from all parameters: growth performance, feed utilization, enzyme activity, carcass composition, and proximate analysis of edible flesh were subjected to one-way Analysis of Variance followed by Duncan's multiple range tests. A significance level of $P<0.05$ was used.

Results

Growth performance

The frog's growth performance regarding final weight, weight gain, and average daily gain were differed among groups ($p<0.05$). The frog fed with frog feed for the first month, catfish feed for the second month, and frog feed for the third month (T5) showed the highest growth performance. However, the specific growth rate was similar with frog fed with frog feed for the first month, herbivorous feed second month and frog feed for the third month (T4), and frog fed with frog feed for the first month, catfish feed for the second month and herbivorous feed for the third month (T2). The survival rate of the T5 group was similar to the control group, which higher than other groups ($P<0.05$). The highest growth rate and survival rate of T5 was the cause of the highest yield in T5 ($P<0.05$) (Table 1).

Table 1. Growth performance and yield of frog fed with switching levels of dietary protein

Growth rate	**Treatment**				
	T1	T2	T3	T4	T5
IW(g/f)	12.88 ± 0.07^{a}	12.80 ± 0.18^{a}	12.88 ± 0.12^{a}	12.85 ± 0.25^{a}	12.95 ± 0.13^{a}
FW (g/f)	222.75 ± 24.39^{c}	334.89 ± 14.75^{b}	147.10 ± 11.18^{d}	339.28 ± 15.01^{b}	399.26 ± 18.34^{a}
WG (g/f)	209.90 ± 24.47^{c}	322.20 ± 14.83^{b}	134.22 ± 15.91^{d}	326 ± 14.66^{b}	386.32 ± 11.89^{a}
ADG (g/f)	2.33 ± 0.26^{c}	3.58 ± 0.16^{b}	1.49 ± 0.12^{d}	3.62 ± 0.16^{b}	4.29 ± 0.20^{a}
SGR (%/)	3.07 ± 0.18^{b}	3.63 ± 0.04^{a}	2.71 ± 0.12^{c}	3.63 ± 0.02^{a}	3.80 ± 0.82^{a}
SR (%)	100.00 ± 0.00^{a}	92.50 ± 3.53^{ab}	82.50 ± 3.53^{c}	92.50 ± 3.53^{ab}	95.00 ± 0.00^{a}
Yield (Kg)	4.46 ± 0.49^{c}	6.20 ± 0.50^{b}	2.51 ± 0.54^{d}	6.28 ± 0.52^{b}	7.33 ± 0.77^{a}

$^{a, b,c}$ Means within a row with common superscript are significantly different ($P<0.05$). n = 30

Feed utilization

The results of feed intake of frog fed with frog feed for all three months (control group) was the highest (P<0.0%) while other groups of frog fed with a different type of feeds have the lower amount of feed intake. From the results, these affected feed utilization in terms of Feed conversion ratio (F.C.R.) and Feed conversion efficiency (F.C.E.) of frogs fed with a different type of feed, especially in the T5, T4, and T2 group were better than T1 (control group). On the other hand, the protein efficiency ratio (PER) of frogs in T1 and T5 was higher than in other groups (P<0.05). Furthermore, the economic performance results demonstrated that total feed cost, income, and profit were perfect in T5, which provided the lowest feed cost and highest income and profit (Table 2). This result pointed that the common lowland frog adjusts feed consumption to suit the nutrients required.

Table 2. Feed utilization of frog fed with switching levels of dietary protein

parameter	**Treatment**				
	T1	T2	T3	T4	T5
FI (g/f/d)	3.81 ±1.52^{a}	1.87 ±0.09^{b}	2.24 ±0.26^{b}	1.97 ±0.14^{b}	1.94 ±0.13^{b}
FCR	1.90 ±0.54^{a}	0.52 ±0.04^{b}	1.52 ±0.35^{a}	0.54 ±0.06^{b}	0.45 ±0.05^{b}
FCE (%)	54.69 ±15.5^{b}	191.85 ±19.09^{a}	67.56 ±15.79^{b}	184.41 ±21.47^{a}	222.19 ±24.35^{a}
PER	0.38 ±0.09^{a}	0.13 ±0.01^{b}	0.11 ±0.01^{b}	0.14 ±0.01^{b}	0.48 ±0.54^{a}
Total Feed cost (Baht)	106.30 ±0.30^{a}	81.43 ±0.35^{c}	79.68 ±0.13^{d}	89.81 ±0.23^{bc}	95.26 ±0.06^{b}
Total Income/^{1} (Baht)	356.40 ±39.0^{c}	496.06 ±40.79^{c}	225.11 ±13.51^{d}	502.81 ±41.41^{b}	621.24 ±17.8^{a}
Total profit (Baht)	250.25 ±38.8^{c}	414.78 ±41.10^{b}	145.43 ±13.32^{d}	412.66 ±41.16^{b}	491.33 ±61.3^{a}

[1] frog price is 80 Baht/kg

^{a,b,c} Means within a row with common superscript are significantly different (P<0.05). n = 30

Protease activity

The enzyme activity data were collected in the second month because, in the first month, all treatments were fed with frog feed that was not different with each other. Thus, the protease activity was determined two times: in the second month and the end of the experiment. The protease enzyme was extracted from the pancreas and intestine of the frog. The results shown in Table 3 in the first time the protease activity extracted from the pancreas from a frog in T4 showed the highest activity followed with T5, T1, T2, and T3, respectively. The first time to collect the protease activity data was the second month which was the start of change on the level of protein in the feeds. It was found that frog in T4 exhibited the highest activity of protease was from pancreas while the activity of protease was extracted from the intestine of frog in T3 was highest ($P<0.05$). At the end of the trial, frogs in T4 and T5 provided the highest protease activity extracted from the pancreas and intestine.On the contrary, frogs in T2 presented the lowest protease activity extracted from the pancreas and intestine ($P <0.05$) (Table 3).

Table 3. Specific activity of serine protease (mU /min/mg/protein) extracted from the pancreas and intestine of frog fed with switching levels of dietary protein

Organs	**Treatment**				
	T1	T2	T3	T4	T5
First time					
Pancreas	1.78 ± 71.00^{b}	31.51 ± 0.34^{c}	22.59 ± 1.18^{d}	86.70 ± 8.74^{a}	6.93 ± 77.63^{ab}
Intestine	1.55 ± 16.93^{b}	4.20 ± 0.32^{d}	23.81 ± 2.65^{a}	1.52 ± 0.24^{e}	10.12 ± 0.23^{c}
Second time					
Pancreas	$\pm69.150.90^{c}$	67.11 ± 1.95^{c}	83.17 ± 4.11^{b}	101.2 ± 0.72^{a}	3.71 ± 100.42^{a}
Intestine	0.67 ± 9.95^{a}	5.40 ± 0.43^{b}	11.33 ± 2.53^{a}	10.60 ± 0.70^{a}	1.28 ± 10.38^{a}

^{a,b,c} Means within a row with common superscript are significantly different ($P<0.05$). n = 30

Carcass composition and flesh quality

The results of carcass composition is shown in Table 4. It was found that the percentage of edible flesh, bone, and viscera were significantly different among the group ($P<0.05$). Frog in control and T5 gave the highest percentage of edible fresh while the percentage of viscera presented the high value in frog in T4 and T3. On the other hand percentage of skin was similar among a group ($P>0.05$).

Table 4. Carcass composition of frog fed with switching levels of dietary Protein

Carcass composition (%)	**Treatment**				
	T1	T2	T3	T4	T5
Edible flesh	32.57 ± 0.28^{a}	28.68 ± 1.18^{bc}	26.51 ± 1.51^{c}	26.76 ± 1.31^{c}	31.91 ± 1.15^{ab}
skin	10.77 ± 0.50	10.55 ± 0.71	9.02 ± 1.30	8.89 ± 0.09	10.68 ± 0.84
bone	31.25 ± 1.32^{a}	25.44 ± 1.72^{c}	30.49 ± 0.96^{b}	26.41 ± 0.67^{bc}	31.57 ± 0.00^{a}
viscera	15.57 ± 1.17^{c}	20.00 ± 1.72^{b}	21.10 ± 1.40^{ab}	23.54 ± 0.82^{a}	15.36 ± 0.00^{c}

^{a,b,c} Means within a row with common superscript are significantly different ($P<0.05$). n = 30.

The flesh quality present in the proximate analysis of edible flesh presented in Table 5 exhibited that all parameters were significantly different ($P<0.05$). The percentage of protein and lipid were outstandingly highest in control (T1) and T5, while the percentage of ash was highest only in T5. Nevertheless, the percentage of fiber was highest in T3 and T4. These results confirm the compensation response because frogs in T1 and T5, which provide the highest growth rate, have the highest percentage of protein and lipid in the flesh.

Table 5. Proximate analysis (%) of edible flesh of frog fed with switching levels of dietary protein

Proximate parameter	**Treatment**				
	T1	T2	T3	T4	T5
Protein	73.5±0.47^{a}	60.76±0.18^{c}	71.37±0.78^{b}	71.15±0.18^{b}	73.84±0.73^{a}
Lipid	7.62±0.38^{a}	5.97±0.68^{c}	6.26±1.03^{bc}	7.27±0.35^{ab}	7.56±0.43^{a}
Ash	3.83±0.03^{c}	3.77±0.03^{c}	3.98±0.09^{b}	4.09±0.09^{b}	4.43±0.04^{a}
Fiber	0.17±0.02^{b}	0.10±0.01^{d}	0.19±0.00^{a}	0.19±0.00^{a}	0.14±0.01^{c}

^{a,b,c} Means within a row with common superscript are significantly different ($P<0.05$). n = 30.

Discussion

The growth performance of frogs in group5 (T5) showed the highest growth rate and survival rate, which provided the highest yield in this group ($P<0.05$). The frog fed with frog feed for the first month, catfish feed for the second month, and frog feed for the third month were better than other groups, especially the control group. The theory of compensation response can explain frog feeding with frog feed throughout the experimental period. The switching of protein level was simulation the starvation or restrict the nutrient requirement, which stimulated the compensatory response of the frog. The growth performance has a relationship with feed utilization which found that frog in T5 has the perfect FCR, FCE especially PER. This data is the cause to promote the growth performance for this group. The frog is in the vertebrate like a teleost fish. Growth rates depend highly on feed utilization (Persson and De Roos, 2006), and starvation is seasonal stress for many species (Wang *et al.*, 2000). Feed deprivation is a repetitive feature in the lifestyle of many species that may explain the term ‘compensatory growth’ whereby fish will exhibit higher feed intake and growth rates after a period of starvation than their rates when fed continuously (Ali *et al.*, 2003).

Teleosts are ectotherms with patterns of indeterminate growth, which allow the examination of the compensatory process at almost every stage of their life cycles (Das *et al.*, 2012). When considering the feed utilization, it followed that frog in T5 showed the relationship between feed utilization, especially PER, and growth performance which the balancing nutrient utilization in the suitable time provides the perfect growth. This result exhibited the overcompensation because of the growth performance of frog in T5, which were fed with the switching level of protein in the diet, was more significant than the control group for which protein in the feeds was continuously available. Besides, the vital mechanism of compensation is hyperphagia in which the rate of food consumption is significantly higher than that shown by animals that have been feeding continuously on an ad libitum ration (Álvarez, 2011). In addition, the switching of protein level in feed seems to restrict or starve the animals which stimulated hyperphagia causing compensatory mechanism.

Furthermore, the rise of growth performance of T5 in response to compensation is due to the promotion of utilization of glucose which provide the protein-sparing effects for better growth, inducing the lipogenesis and decreasing amino acid catabolism (Kumkhong *et al.*, 2020). The discovered of Hector *et al.* (2011) exhibited that brown tree frog tadpoles (*Litoria ewingii*) fed with reduced rations for two weeks, c. 35% of the control group's larval period, before being returned to the diet of the controls exhibited faster weight gain upon refeeding and reached a final size more significant than the control tadpoles.

Moreover, the results from this study are similar to that of Rodjaroen *et al.* (2020), who found the optimal feeding schedule for mono-sex male tilapia is alternately every other day that one day for high protein (32.80%) feeding and one day for low protein (28.64%) feeding which provided the growth performance similar with a control group which feeds high protein feed throughout the study. However, the compensation response of the frog was more responsive because overcompensation occurs (Álvarez, 2011). Overcompensation is demonstrated when the animals with a proficient restricted ratio achieve a more significant size at the same age as nonrestricted animals (Das *et al.*, 2012). In addition, the study on compensatory growth in Nile tilapia fed with 18% protein supplemented with 5% protein concentrate only at first month and followed with 32 % protein feed and feeding twice every other day provided the overcompensation (Klahan *et al.*, 2020). Moreover, the current study was similar with Kumar *et al.* (2013), who found that alternate-day feeding with normal protein (30% protein) and low protein (25% protein) diet in rohu promoted the growth performance similar with rohu fed with the regular protein diet. The current study has similar findings as Kumkhong *et al.* (2020) who pointed that Nile tilapia fry with low-protein/high-carbohydrate (LP/HC) diet since first feeding for four weeks and at the final, early HC stimulus had significant positive nutritional programming of metabolism in Nile tilapia (an omnivorous fish).

The feed utilization and economic performance results was best in T5, this pointed out that the common lowland frog had adjusted to feed consumption to suit the nutrients required. Compensatory growth response was born from endogenous energy reserves, altering endocrine profiles that enhance appetite and growth potential. During this catabolic phase (fasting or low nutrient requirement), elevated ghrelin and growth hormone (GH) production increase appetite and protein-sparing lipolysis, while insulin-like growth factors (IGFs) are suppressed, primarily due to hepatic GH resistance. During refeeding or return to the normal nutrient, temporal hyperphagia provides an influx of energy and metabolic substrates allocated to somatic growth by resumed IGF signaling (Won and Borski, 2013). Rodjaroen *et al*. (2020) reported that the economic performance of Nile tilapia was improved by appropriate choice of mixed feed schedule alternately every other day with High protein and Low protein (1HP/1 LP). Furthermore, these result were similar in many species such as Juvenile *Pangasianodon bocourti* (Jiwyam, 2010), spotted snakehead, *Channa punctatus* (Jindal *et al*., 2010), and common carp, *Cyprinus carpio* (Sardar *et al*., 2011).

The lowest protease activity was extracted from pancreas and intestine of frogs in T2, while the highest protease activity was in T4 and T5. These indicated that the protease production and action varied with the protein intake. It is known that protease is produced from the pancreas and action at intestine and its presence in the changing from low protein to high protein intake that affected on the highest production and action as shown in frog in T3 that changing from herbivorous feed (low protein) to catfish feed (high protein). In addition, these data were discovered in T4 and T5 that changed from herbivorous and catfish feed (low protein) to frog feed (high protein). The protease activity was related to PER, which explained to increase PER that presented the T5 group. However, no changing protein in feed and protein intake, but it was in high contained in feed for a long time, affected production and action in the high level of protease present in the control group (T1). Feed digestion is an essential metabolic process that controls the digestive enzyme (Lingam *et al.,* 2019; Gisbert *et al.,* 2009; Abolfathi *et al*., 2012). It is well know that the digestive enzyme activities are affected by the nutrient aquafeed feeding practices (Klahan *et al*., 2009). According to Kumar *et al*. (2013), this study presented that digestive enzyme activity of rohu fed with alternate feeding of 1-day diet high protein followed by 1-day diet low protein (1A/1B) was also highest. In addition, according to Lingam *et al*. (2019), this current result reported that the stunting of milkfish for eight months positively affects its digestive enzyme activities and carcass quality turn.

The carcass composition of a bit of protein switching with frog feed and catfish feed in T5 was affected by the edible flesh's weight, and bone exhibited a higher percentage in bone and edible flesh. It indicated that the frog's compensatory growth pattern deposits more body mass by accumulating more energy reserves and nutrients, especially protein retention, according to PER value. A feasibility increase in IGF-I may induce increased protein synthesis, as suggested by increased muscle levels of RNA and elongation factor-2 during compensatory growth (Therkildsen *et al*., 2004), including N balance and increased N retention (Ishida *et al*., 2012). The regulation and function of the IGF-I structure appear similar in fish and mammals and many fish species (Reinecke *et al.*, 2005). The results pointed that the response of compensatory mechanism in frog similar with fish by explained with the closure mechanism.

These results of flesh quality confirm the response of compensation because frogs in T1 and T5 provided the highest percentage of protein and lipid in the flesh. It indicated that the balanced nutrient, especially protein from switching dietary protein levels, was suitable for these groups. During fasting or receiving low requirement nutrient rising plasma GH was recorded by MacKenzieetal (1998), along with the related somatolactin (Mingarro *et al.*, 2002), protects non-expendable tissue such as vital muscle organs from being catabolized by metabolizing fat over protein. This lipolytic function has been demonstrated in fish with exogenous GH treatment *in vivo* in coho salmon (*Oncorhynchus kisutch*; Sheridan, 1986) and *in vitro* gilthead seabream (Sparusaurata) adipocytes (Albalat *et al.*, 2005) and it was an acritical adaptation to surviving negative energy periods. Despite this, the protein and lipid percentage in the frog's flesh in T5 were similar to T1 (control). Most research exhibited that the percentage of lipid in an animal who was restricted feed or nutrient would be depressed more than the control group, which was different from the current study which found in gilthead seabream. The lipolysis was significantly higher in adipocytes from fish-fed feed containing plant protein which provided low protein, than in adipocytes from fish meal-fed fish. Together, glucagon and especially GH play a significant role in controlling adipocyte lipolysis (Albalat *et al*., 2005). In contrast, frog fed with frog feed for the first month, catfish feed for the second month, and frog feed for the third month in T5 had no adipose tissue present in the abdomen, similar to the controls group, which provided a percentage of viscera which lower than other groups. In addition, the protein intake in T5 was not lowered enough to stimulate lipolysis caused percentage of lipid in the flesh was high, similar to control.

These results were almost similar to Rodjaroen *et al*. (2020), who found that mixed feeding schedules alternately every other day (1HP/1 LP), every other week (7HP/7 LP), and every two weeks (14HP/14 LP) for Nile tilapia were no adversely affected on flesh quality and carcass composition in any experimental group. Nevertheless, the current study found that it also negatively affected the flesh quality, and promoted a high percentage of protein and lipid. Therefore, the common lowland frog response on compensation was representative of growth performance, feed utilization, and it had not adversely affected on carcass composition and flesh quality. Besides, the common lowland frog showed the response on the protein level, which emphasized that protein is an essential nutrient of the frog. Furthermore, the most important was feeding regime by using switching levels of dietary protein is exhibited the highest economic performance by decreasing feed cost and provide the highest profit. Therefore, the switching levels of dietary protein is related to feeding frog with frog feed for the first month, catfish feed for the second month, and frog feed for the third month was the suitable feeding regime by the response on compensation which promoted the growth performance and feeds utilization and provided the highest yield and cost-effectiveness

References

A. O. A. C. (2000). Official methods of analysis. Virginia Association of Official Analytical Chemist, Inc.

Abolfathi, M., Hajimoradloo, A., Ghorbani, R. and Zamani, A. (2012). Effect of starvation and re-feeding on digestive enzyme activities in juvenile roach, *Rutilus rutilus* caspicus. Comparative Biochemistry & Physiology, 161:166-173.

Álvarez, D. (2011). Effects of Compensatory Growth on Fish Behavior. Encyclopedia of Fish Physiology: From Genome to Environment, 1:752-757

Albalat, A., Gómez-Requeni, P., Rojas, P., Médale, F., Kaushik, S., Vianen, G. J., Van den Thillart, G., Gutiérrez, J., Pérez-Sánchez, J. and Navarro, I. (2005). Nutritional and hormonal control of lipolysis in isolated gilthead seabream (*Sparus aurata*) adipocytes. The American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 289:259 -265.

Ali, M., Nicieza, A. and Wootton, R. J. (2003). Compensatory growth in fishes: a response to growth depression. Fish and Fisheries, 4:147-190.

Amin, A. K. M. R., Bapary, M. A. J., Islam, M. S., Shahjahan, M. and Hossain, M. A. R. (2015). The Impacts of Compensatory Growth on Food Intake, Growth Rate and Efficiency of Feed Utilization in Thai Pangas (*Pangasius hypophthalmus*). Pakistan Journal of Biological Sciences, 8:766-770.

Bezerra, R. S., Lins, E. J. F., Alencar, R. B., Paiva, P. M. G., Chaves, M. E. C., Luana, C. B. B. and Carvalho, L. B. Jr. (2005). Alkaline proteinase from intestine of Nile tilapia (*Oreochromis niloticus*). Process Biochemistry, 40:1829-1834.

Capellán, E. and Nicieza, A. G. (2007). Non-Equivalence of Growth Arrest Induced by Predation Risk or Food Limitation: Context-Dependent Compensatory Growth in Anuran Tadpoles. Journal of Animal Ecology, 76:1026-1035.

Castell, J. D. and Tiews, K. (1980). Report on the EIFAC, IUNS and ICES. Working group on the standardization of methodology in fish nutrition research, Hamburg, Federal Republic of Germany.

Das, A. P. U., Tanmoy, G. C., Sagar and C. M. (2012). Compensatory Growth in Fishes A Boon To Aquaculture. Aquaculture Europe, 37:20-23.

Gabriel, N. N., Omoregie, E., Martin, T., Kukuri, L. and Shilombwelwa, L. (2018). Compensatory Growth Response in Oreochromis mossambicus Submitted to Short-Term Cycles of Feed Deprivation and Refeeding. Turkish Journal of Fisheries and Aquatic Sciences, 18:161-166.

Gimenez, A. V. F., Fernandez, I., Preciado, R. M., Oliva, M., Tova, D. and Nolasco, H. (1999). The activityof digestive enzyme during the molting stage of the arched swimming Callinectes Arcautus orday, 1863. (Crustacea : decapoda: portunidae). Bulletin of Marine Science, 65:1-9.

Gisbert, E., Gimenez, G., Fernandez, I., Kotzamanis, Y. and Estevez, A. (2009). Development of digestive enzymes in common dentex, *Dentex dentex* during early ontogeny. Aquaculture, 287:381-387.

Halver, J. E. and Hardy, R. W. (2002). Fish Nutrition, third ed. Academic Press, New York.

Hector, K. L., Bishop, P. J. and Nakagawa, S. (2011). Consequences of compensatory growth in an amphibian. Journal of Zoology, 286:93-101.

Ishida, A., Kyoya, T., Nakashima, K. and Katsumata, M. (2012). Nitrogen balance during compensatory growth when changing the levels of dietary lysine from deficiency to sufficiency in growing pigs. Animal science journal, 83:743-749.

Jindal, M, Yadava, N, Jain, K and Gupta, R. (2010). Effect of Two Dietary Protein Levels on Body Weight and Composition in *Channa punctatus* (Bloch.) Fingerlings. Turkish Journal of Fisheries and Aquatic Sciences, 10:203-208.

Jiwyam, W. (2010). Growth and compensatory growth of juvenile *Pangasius bocourti* Sauvage, 1880. Aquaculture, 306:393-397.

Klahan, R., Areechon, N., Yoonpundh, R. and Engkagul, A. (2009). Characterization and activity of digestive enzymes in different sizes of Nile tilapia (*Oreochromis niloticus* L.). Agriculture and Natural Resources, 43:143-15.

Klahan. R., Youngsoi, B. and Pimpimol. T. (2020). The evaluation of growth performance, feed utilization, and flesh quality of Nile tilapia (*Oreochromis Niloticus*) fed with different feeding regime. 7th International Conference on Fisheries and Aquaculture 2020 (ICFA 2020), 81 p.

Kumar, P., Jain, K. K., Munilkumar, S., Sahu, P. N. and Pal, K. A. (2013). Effect of feeding normal and low protein diet alternately to *Labeo rohita* fingerlings on growth performance and biochemical composition. Int. J. Science & Knowledge, 2:3-13.

Kumkhong, S., Marandel, L. Plagnes-Juan, E., Veron, V., Panserat, S. and Boonanuntanasarn, S. (2020). Early feeding with hyperglucidic diet during fry stage exerts long-term positive effects on nutrient metabolism and growth performance in adult tilapia (*Oreochromis niloticus*). Journal of Nutritional Science, 9:1-14.

Lingam, S. S., Paramita, B. S., Narinder, K. C., Kurcheti, P. Muralidhar, A. P., Karthireddy, S. and Martin, X. K. A. (2019). Duration of stunting impacts compensatory growth and carcass quality of farmed milkfish, *Chanos chanos* (Forsskal, 1775) under field conditions. Scientific Reports, 9:16747.

Lowry, C. O., Rosebrough, N., Farr, A. and Randall, R. (1951). Protein measurement with the Folin phenol reagent. J biol Chem, 193: 265-75.

MacKenzie, D. S. (1988). Thyroid function in red drum. Contrib. Mar. Sci. Supp, 30: 139-146.

Mingarro, M., de Celis, S. V. R., Astola, A., Pendón, C., Valdivia, M. M. and Pérez-Sánchez, J. (2002). Endocrine mediators of seasonal growth in gilthead sea bream (*Sparus aurata*): the growth hormone and somatolactin paradigm. General and comparative endocrinology, 128: 102-111.

Näslund, J., Pauliny, A., Blomqvist, D. and Johnsson, J. I. (2015). Telomere dynamics in wild brown trout: effects of compensatory growth and early growth investment. Oecologia, 177:1221-1230.

Persson, L. and De Roos, A. M. (2006). Food‐dependent individual growth and population dynamics in fishes. Journal of Fish Biology, 69: 1-20.

Reinecke, M., Björnsson, B. T., Dickhoff, W. W., McCormick, S. D., Navarro, I., Power, D. M. and Gutiérrez, J. (2005). Growth hormone and insulin-like growth factors in fish: Where we are and where to go. General and Comparative Endocrinology, 142:20-24.

Rodjaroen, S., Thongprajukaew, K., Jaihao, P., Saekhow S. and Nuntapong, N. (2020). Mixed feeding schedules switching between dietary crude protein levels for mono-sex male Nile tilapia (*Oreochromis niloticus*). Aquaculture Reports, 18:1-8.

Sardar, P., Sinha, A. and Datta, S. (2011). Effect of mixed feeding schedules with varying dietary protein levels on the growth performances of common carp (*Cyprinus carpio* Linn.). Indian Journal of Animal Sciences, 81:537-542.

Sheridan, M. A. (1986). Effects of thyroxin, cortisol, growth hormone, and prolactin on lipid metabolism of coho salmon, *Oncorhynchus kisutch*, during smoltification. General and comparative endocrinology, 64: 220-238.

Somsueb, P. and Boonyaratpalin, M. (2002). Optimum protein and energy levels for the Thai native frog, *Rana rugulosa* Weigmann. Aquaculture research, 32:33 -38.

Therkildsen, M., Vestergaard, M., Busk, H., Jensen, M.T., Riis, B., Karlsson, A. H., Kristensen, L., Ertbjerg, P. and Oksbjerg, N. (2004). Compensatory growth in slaughter pigs in vitro muscle protein turnover at slaughter, circulating IGF-I, performance, and carcass quality. Livestock Production Science, 88:63-75.

Urbinati, E. C., Sarmiento, S. J. and Takahashic, L. S. (2014). Short-term cycles of feed deprivation and refeeding promote full compensatory growth in the Amazon fish matrinxã (*Brycon amazonicus*). Aquaculture, 433:430-433.

Vonesh, R. J. and Bolker, M. B. (2005). Compensatory larval responses shift trade-offs associated with predator-induced hatching plasticity. Ecology, 86:1580-1591.

Wang, Y. Yibo, C., Yunxia, Y. and Fasheng, C. (2000). Compensatory growth in hybrid tilapia, *Oreochromis mossambicus X O. niloticus*, reared in seawater. Aquaculture, 189:101-108.

Wilson, R. P. (2002). Amino Acids and Proteins. Fish Nutrition. In : Fish nutrition. Halver, J. E., Hardy, R. W., third ed. Academic Press, New York, 143-179.

Won, E. T. and Borski, R. J. (2013). Endocrine regulation of compensatory growth in fish. Front Endocrinol, 4:1-13.

Xu, C., Xu, W. and Lu, H. (2014). Compensatory growth responses to food restriction in the Chinese three-keeled pond turtle, *Chinemys reevesii*. Springer Plus, 3:687.

Ziheng, F., Xiangli, T. and Shuanglin, D. (2017). Effects of Starving and Refeeding Strategies on the Growth Performance and Physiological Characteristics of the Juvenile Tongue Sole (*Cynoglossus semilaevis*). Journal of Ocean University of China, 16:517-524.

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