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Effect of Greenhouse Cages Integrated with using Solar Energy on the Growth Performance on Freshwater Fish

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Abstract— **Currently, aquaculture based employment has been impact on fishery industry and gained awareness in worldwide. Northern parts of Thailand, cage fish farming are very important cultivation. It has contributed substantially to livelihoods, food demand, employment and income. Environmental factors are significant role in the fish culture especially, the temperature. It is fairly low in the Northern part of Thailand during in the winter, air temperature drops below 15 °C and difference between day and night about 15-20 °C. Generally, the appropriate and optimum temperature of fish culture was 28-32 °C. The average initial weight of fishes were 2.54±0.11 g at cultured for 120 days in 3 treatments, normal fish cage (T-A), greenhouse fish cage (T-B) and greenhouse fish cage was integrated with reduce heat loss system (T-C). The study investigation revealed that average water temperature and highest value were observed in treatments (T-C) (27.6 °C), followed by treatments (T-B) (26.7 °C) and treatments (T-A) (26.4 °C), respectively. After 120 days of culture, fishes in treatments (T-A) had significantly higher weight (121.35±5.33 g/fish) then treatments (T-B) (135.05±5.66 g/fish) and treatments (T-C) (143.87±5.07g/fish). Compared with treatment (T-C) with treatments (T-A) and (T-B) achieved more daily weight gain, equal to 16.1% and 6.8%, respectively. Also the specific growth rate was equal to 4.17% and 1.49%, respectively. Furthermore, the study focused on increasing and provides the optimum temperature using thermal performance of greenhouse fish cages integrated with hot air aerator through solar energy. In this study, Climbing perch (*Anabas testudineus*) fish was used. The system was developed for heating the fish cages with solar energy by greenhouse cage design is equipped with insulation to reduce heat loss by used foam and covered with bamboo which is economically helpful for fish farmer. Consequently, the results confirmed that possible to apply and increase water temperature through greenhouse fish cage integrated with reducing heat loss system.**

Index Terms— **Climbing perch, Fish Cage, Greenhouse, Temperature, Solar Energy.**

I. INTRODUCTION

Aquaculture is the fastest growing food production industry and the vast majority of aquaculture products are derived from Asia. The quantity of aquaculture products directly consumed is now greater than that resulting from conventional fisheries [1]. As aquaculture production continues to increase and intensify, both its reliance and its impact on ocean fisheries are likely to expand even further [2]. Fish are a source of high quality protein, vitamins and essential minerals but, above all, a virtually unique, rich source of omega-3 long-chain poly-unsaturated fatty acids [3]. Thailand has a growing population (1 percent growth rate per annum in 2013-14) and needs large sources of protein foods. The present per capita availability of protein is necessary in daily requirements. Fish is an excellent and relatively a cheaper source of animal protein of high biological value.

Since there are many freshwater farms were increasing yearly basis in Thailand. Freshwater fish as a protein source is very importance source especially Northern part of Thailand. On 2012, freshwater fish farm areas containing 936,553 acres at Thailand, northern region freshwater fish farms had 142,055 acres. It was producing 673,700 tons with total value of approximately 36,264.9 million THB (1,032.81 million USD) in the northern part of Thailand [4]. Recently the using poly cage net on the river or lagoon have been increased, moreover in the nation poly cage net culture on the river or lagoon up to 703 acres and in northern part of Thailand up to 103 acres. In addition, farmers very interested in the freshwater fish farming and increased 14.56% last two years [5]. At present, the climbing perch fish have much successful business due to the development of improved varieties in Thailand. Because climbing perch have high growth rate, grow big size, resistance to disease and popular in local markets.

However, the influence of water temperature affects the fish growth. The fish will thrive in temperature range of 28-32 °C. If temperature is higher or lower it could affect the growth rate of fish [6]. Especially in the Northern part of Thailand, temperature is relatively low. In winter, air temperature drops below 15 °C and the temperature difference between day and night about 15-20 °C [7]. The fishes were cultured in the winter and raining seasons there was dwindling number. In contrast, the price of fish was increasing during this season 50-80% from regular price. Farmers have to manage and increase the quality for culturing fish in cages. The temperature is effects of culture fishes in the winter or raining season directly. Low water temperature is affecting the fish growth rates. If low temperature occur fishes could not eat. That's main reason, fish had a dwindling number.

According to [8] open and inside greenhouse condition can identify the influence of water temperature on fish growth during winter period and temperature can increase (3.58-6.79

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°C) compared with outside tanks. Zhu et al. [9] stated that from the simulation results, in a 1-m pond, a passive polyethylene greenhouse pond systems can be achieved 5.2°C increasing in water temperature compared with outside air temperature.

In general, farmers have to cultured fish until growth to mature around 6-8 months to be sold But it can shorten the time to culture with about 3-4 months which must to control water temperature is in range of 28-32 ºC at winter and rainy seasons. This approach could reduce production costs and save time. However, different types growing methods and detailed information of culturing climbing perch still not fully developed. Cultured cage fishes in river or lagoon for space-saving and water usage studies needed. In addition, the solar energy could be applicable for low-cost energy to keep the water temperature maintenance around culturing area. Several researchers reported open air-pond temperature system, greenhouse or plastic shelter pond and greenhouse thermal environment under both steady and transient condition [9-11]. Furthermore, greenhouse fish cages by integrated with hot air aerator using solar energy along with insulation to reduce heat loss by using foam and covered with bamboo. Bamboo is very strong and can use in side river or lagoon for long time. And also can find in area which is economically helpful for fish farmer. Accordingly, this paper describes an experimental study of the impact of net cages culturing, detailed information of culturing climbing perch with outdoor fish cage, greenhouse fish cage and greenhouse fish cage with hot air aerator. In addition, in this study applied solar energy as a source of low-cost energy to keep the water temperature increases using plastic greenhouses to raise the temperature.

II. Materials and Methods

A. Location of experimental area and fish cage setting

The study was carried out between July and November 2015 in a lagoon (18° 53' 24" N 99° 2' 16" E), near to Maejo University, Chiang Mai, Northern part of Thailand. The experiment cages were shown in figure 1. And demonstrated the layout diagram of experimental greenhouse with fish cages were shown in figure 2.

The experiment was divided into three units including 1) normal fish cage i.e. outdoor fish cage (treatment A, T-A), spread a poly cage net, nylon net was used (pour size = 2 cm, length = 200, width = 300, height=150 cm), 2) greenhouse fish cage (treatment B, T-B), was construct by parabolic roof structure made from poly ethylene (0.15 mm, UV 7%) and five blue plastic tanks for floats on water surface. The system size (width= 330 cm, length=400 cm, and height= 205 cm) along with covered and spread a poly cage net (layer = 2 mm, size length = 200 cm, width =300 cm and height =150 cm). Inside greenhouse fish cage was allowed to 1 meter depths from the water surface. And greenhouse fish cage was integrated with reduce heat loss system (treatment C, T-C) were shown in figure 2. Furthermore, treatment 2 (T-B) was used foam and covered with bamboo to reduce heat loss and size including length = 210 cm, width =320 cm and height =150 cm.

B. Organism

Climbing perch (*Anabas testudineus*) was used. The initial weight of fish average was 2.55 ± 0.11 g/fish. Three hundred climbing perch fishes were used in this experimental study. The study found that climbing perch have the patience, afforded and pet-friendly. An area of 1-2 m2 can be fed for consumption or sell it. Because in area 1 m × 1 m × 0.8 m (width × length × deep) can release the fish were 35-50 fishes

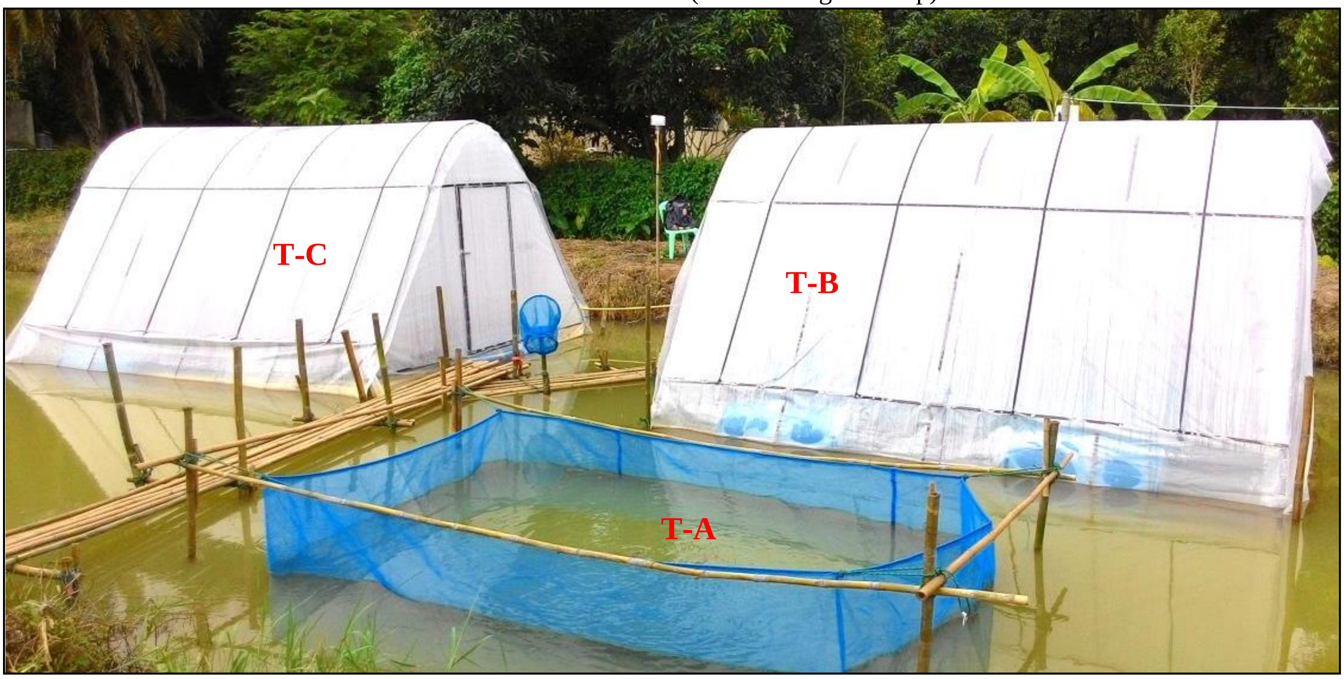

Figure 1. Experiment Cages: Normal fish cage (T-A), Greenhouse fish cage (T-B) and Greenhouse fish cage integrated with reduce heat loss system (T-C)

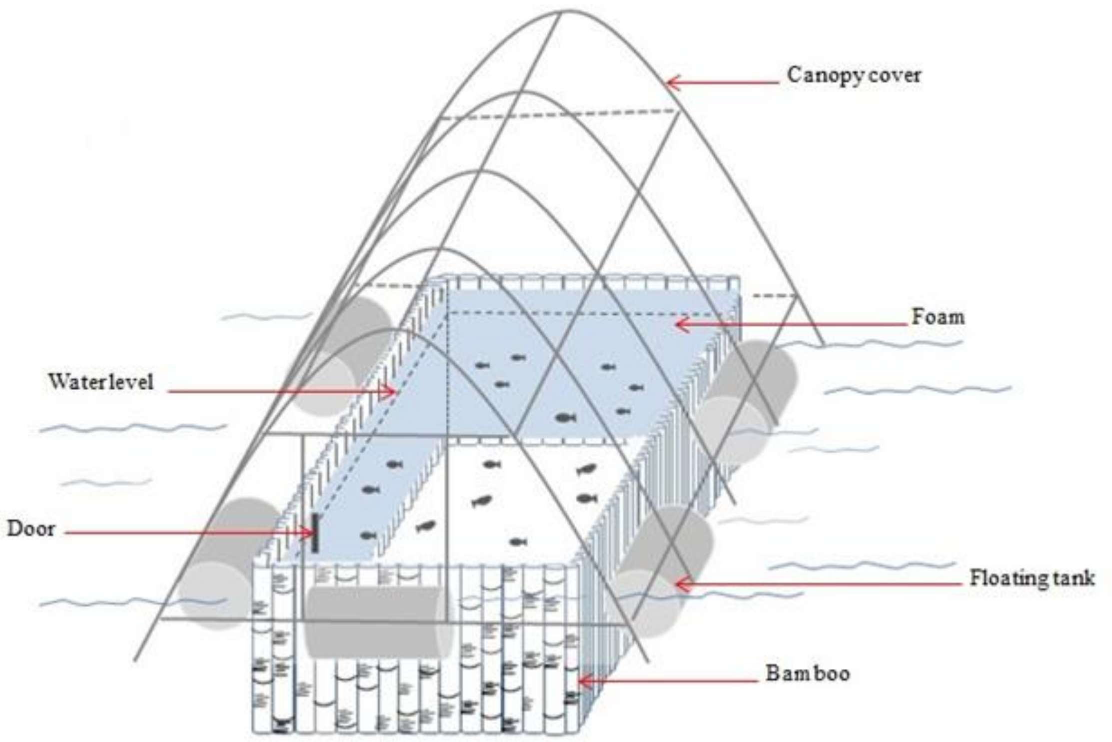

Figure 2. Greenhouse fish cage integrated with reduce heat loss system

C. Experimental diets and feeding

Climbing perch fish were fed by floating food (manual) method during the entire experimental period. Fish feed was formulated with locally available materials including soybean, rice Bran, compressed coconut meal, steamed soybeans and corn. Feed containing protein 25%, fat 3% and other nutritious 8% with humidity 12%. Feeds were supplied to fish at a frequency of 3 times per day (06:00-07:00 am; 12:00-13:00 pm; and 05:00-06:00 pm) and 3% by weight.

D. Data analysis

All physico-chemical analyses were carried out during study period and detailed methods were presented in Table 1. The length of experimental fish was measured in centimeters with an ordinary scale. Weight was measured to the nearest by electronic balance (Model SF-400A AFD), with the help of small plastic bucket. Solar radiation was measured by a solar power meter (Model DT-1307), and it placed on the roof of the greenhouse fish cage. Thermocouples (Type K) used to measure air temperatures and water temperatures. Water temperatures were measured 10.0, 30.0, 100.0 cm and soil surface in lagoon depths from water surface of lagoon. Thermocouples were recorded every 10 minutes by a multi-channel data logger (Lega, Model TM-947SD). The experiments were started at 6.00 am and continued till 6.00 am another day (24 h). Water samples were collected from the experimental zone at lagoon for nutritional and physiochemical analyzes. The sample was transferred to the laboratory at the Faculty of Fisheries Technology and Aquatic Resources, Maejo University, Chiang Mai, Thailand.

Table 1: Physiochemical parameter in lagoon.

Parameter	Equipment or method
pH	Method 423 (pH value)
DO (mg/l)	Method 421B (azide modification)
EC (ds/m) Turbidity (mg/l)	DO meter (YSI Model 59)
TKN (mg/L)	Method 420A (macro-kjeldahl method) with Method 417B (nesslerization method (direct & following distillation)) for final ammonia.
Alkalinity ($mgCaCO_3/L$)	Method 403 (alkalinity)
Temperature (°C)	Data logger (Lega, Model TM-947SD), and Thermocouples (Type K)
COD (mg/l)	Method 508B (closed reflux, titrimetric method)

a All processes follow standard method.

E. Experimental procedure:

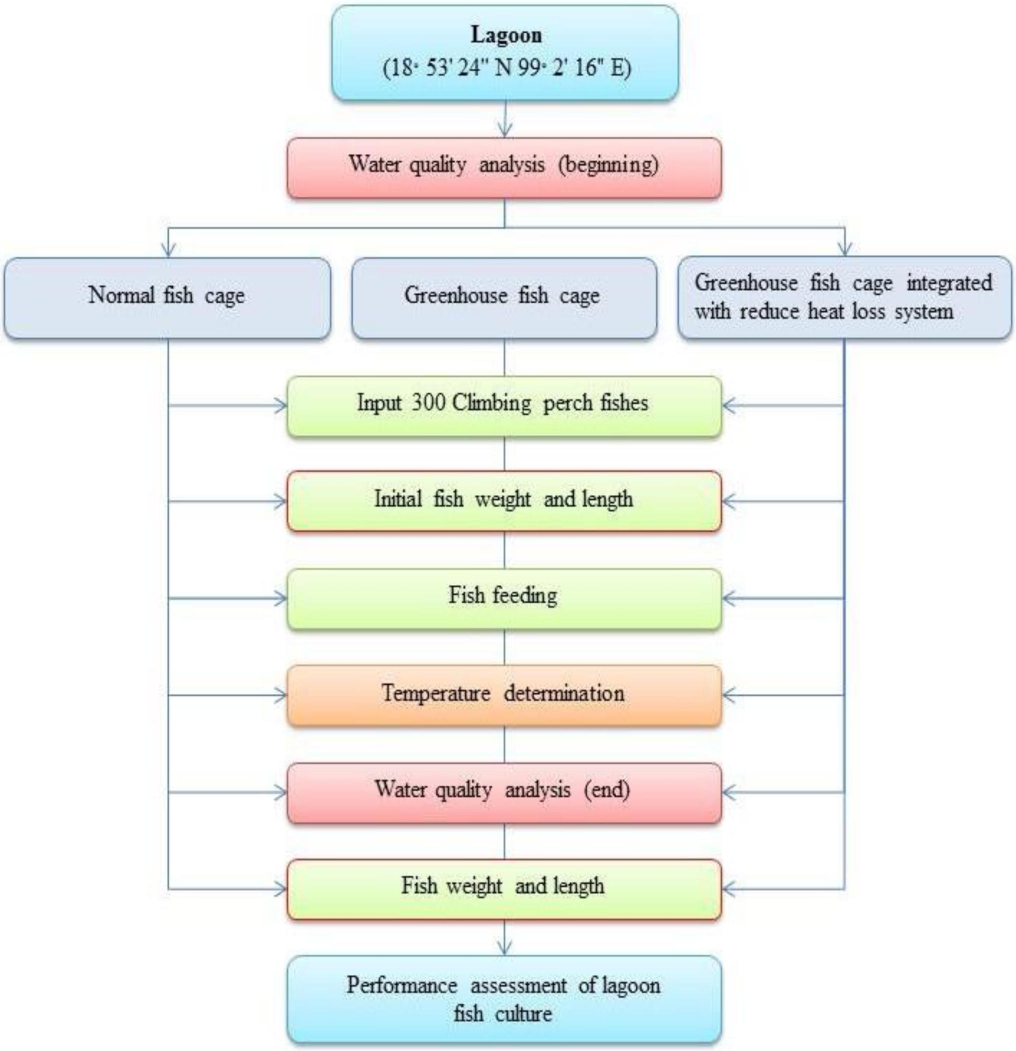

Figure 3. Experimental procedure

III. RESULTS AND DISCUSSION

A. Growth Performance of Climbing perch

Climbing perch (*Anabas testudineus*) is a freshwater perch in tropical and subtropical Asia. Climbing perch has high fecundity. It is an Anabantidae (family of perciform fish) which occurs mainly in lakes, swamps and estuaries sluggish flowing canals, medium to large rivers, flooded fields and stagnant waters in most tropical and subtropical Asia [12]. Climbing perch is an economically important fish species in Thailand. Fish growth conditions and physicochemical parameters results were presented in Table 2. Fish average weight and length of this study experiment cages shown in Figure 4 and 5.

Table 2: Physiochemical parameter in lagoon.

No.	Elements	Before feeding fish			After feeding fish		
		Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
1.	pH	6.46±0.08	6.38	7.09	6.96±0.12	6.86	7.09
2.	DO (mg/L)	1.50±0.17	1.32	1.65	8.25±0.05	8.20	8.30
3.	EC (ds/m)	13.07±0.25	12.80	13.30	121.57±0.40	121.20	122.00
4.	Turbidity (NTU)	240.40±26.90	220.50	220.50	629.00±30.61	600.00	661.00
5.	TKN (mg/L)	0.80±0.07	0.75	0.85	22.42±0.00	22.42	22.42
6.	Alkalinity (mg_{CaCO3}/L)	250.00±0.00	250.00	250.00	200±70.71	150.00	250.00
7.	COD (mg/L)	78.00±2.83	76.00	64.00	62.00±2.83	60.00	64.00

* Note: water features of Greenhouse fish cage integrated with reduce heat loss system (T-C) for four mounts.

Environmental factors affecting fish culture including adequate oxygen, proper temperature, transparency, limited levels of metabolites [13] and water quality has influence on fishes [14]. For understating on the fish cultivation important factor is water determinations. It could help us know the success or failure of an aquaculture operation [15]. The study was carried out between rainy seasons to start winter on lagoon for agriculture. Form beginning to inspect water quality analysis before release the fish. From 120 days culture, the results of water quality analysis show that pH was 6.46±0.08 to 6.96±0.12, DO was 1.50±0.17 mg/l to 8.25±0.05 mg/l, turbidity was 240.40±26.90 NTU to 629.00±30.61 NTU. The optimum pH for fish is between 6.5 and 8.5. The pH distribution of the surface waters showed that it was slightly alkaline. High pH values of 8.0/8.1 were during the dry season while pH dropped during the rainy and harmattan seasons. This drop in pH from 8.1 - 7.3 was probably due to the stirring effect of the raining that have more waters [16]. Dissolved oxygen affects the growth, survival, distribution, behavior and physiology of the aquatic animals [17].

Their optimum concentration is 8-10 mg per liter, and if the level declines below 3 mg per liter could affect the fish growth [18]. Turbidity is the resultant effect of several factors such as suspended clay particles, dispersion of plankton organisms, particulate organic matters and also the pigments caused by the decomposition of organic matter [19-20]. Fish culture during 20-30 NTU is suitable. In this study is observed over more turbidity and during 20-30 NTU is suitable for fish culture [21]. From the experimental results were observed over more turbidity because the lagoon is clay and closed. The alkalinity results were 250±0.00 mg$CaCO_3$/L to 200±70.71 mgCaCO3/L. Good value for fish culture is 50-300 mg L^{-1} [22]. Higher than 20ppm indicates poor status of water quality, 20-50 ppm shows low to medium, 80-200 ppm is desirable for fish/prawn and less than 300 ppm is undesirable due to non-availability of CO_2 [23]. The Electrical conductivity of water was 13.07±0.25 ds/m to 121.57±0.40 ds/m, total Kjeldahl nitrogen were 0.80±0.07 mg/L to 22.42±0.00 mg/L. And the COD of water confirmed that 78.00±2.83 mg/L to 62.00±2.83 mg/L; and the ideal value of COD should be less than 50 mg/l for fish culture [24]. Consequently, the water quality results were encouraged the fish cultivation in this lagoon.

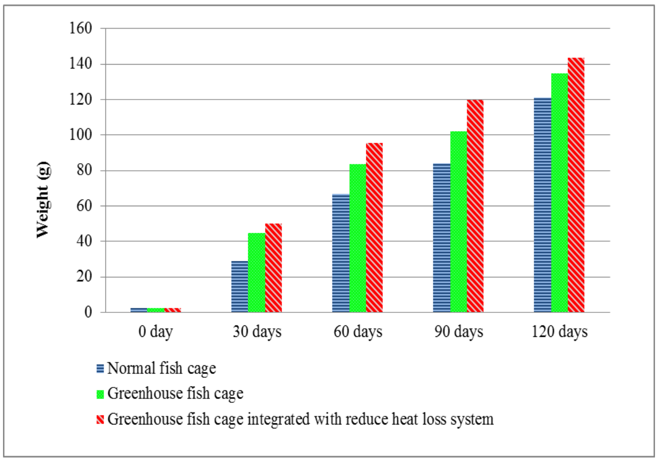

Figure 4. Fish weight of this experimental study

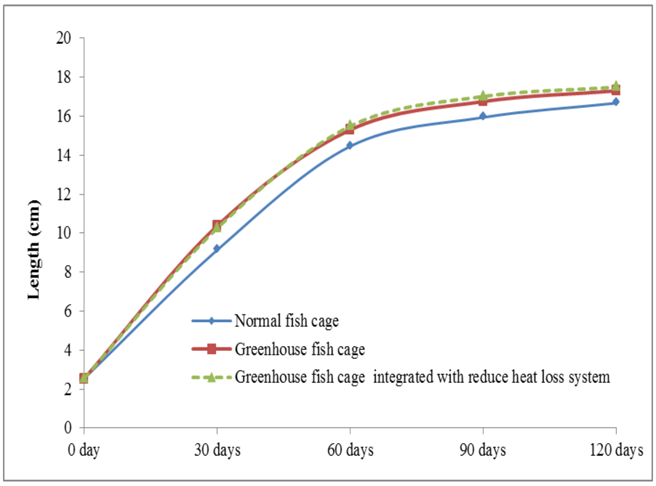

Figure 5. Fish length of this experimental study

There are very few reports available of common climbing perch fish rearing in greenhouse fish cage in Thailand and abroad. The temperature is an important parameter for fish growth. Greenhouse water showed uniform water temperature throughout the day and night and observed that fish under greenhouse had elevated consumption and activity [25]. Temperature variation of only a few degrees represents a proportionally large change for fish growth and survivability [26]. The growth of the fish on different sample is consistent with culture for eating food. Water temperature contributes to the appearance of eating fish. Cultured for 120 days in 3 treatments, normal fish cage (T-A), greenhouse fish cage (T-B) and greenhouse fish cage was integrated with reduce heat loss system (T-C) were cultured for 120 days in 3 treatments, normal fish cage (T-A), greenhouse fish cage (T-B) and greenhouse fish cage was integrated with reduce heat loss system (T-C). Will see clearly Compared treatments (T-C) with treatments (T-A) and (T-B) will grow well over 15.65% and 6.13%, respectively were shown in Table 3. Since the metabolism of fish is affected by temperature and other environmental factors [27]. Therefore, using plastic film covering over ponds resulted in higher growth performance and lower production cost. It is therefore a promising method for farmers to culture the freshwater during the cold season [28].

The initial weight of fish average was 2.54±0.11g/fish and the initial length of fish average was 2.54±0.16 g/fish for Experiment Cages: Normal fish cage (T-A), Greenhouse fish cage (T-B) and greenhouse fish cage integrated with reduce heat loss system (T-C). After four mounts that finally weight of fish average was 121.35±5.33, 135.05±5.66, and 143.87±5.07 g/fish, respectively. And finally length of fish average was 16.68±0.36, 17.31±0.44, and 17.49±0.33 g/fish, respectively. So daily weight gain (DWG) was 0.99, 1.10, and 1.18 g/day, respectively. Specific growth rate (SRG) was 3.22, 3.31, and 3.36 %/day, respectively. And Survival Rate was 87.7, 86.0, and 90.3%, respectively.

Table 3: Fish growth analysis .

Simple code	Weight (g)		Length (cm)		DWG (g/day)	SGR (%/day)	Survival Rate (%)
	Start	End	Start	End			
T-A	2.54±0.11	121.35±5.33	2.54±0.16	16.68±0.36	0.99	3.22	87.7
T-B	2.54±0.11	135.05±5.66	2.54±0.16	17.31±0.44	1.10	3.31	86.0
T-C	2.54±0.11	143.87±5.07	2.54±0.16	17.49±0.33	1.18	3.36	90.3

* Note: Daily weight gain (DWG), Specific growth rate (SRG)

B. *Temperature difference in three types of cage system*

Temperature may even play a part since many fish species are known to become more aggressive under warm and very cold conditions. Furthermore, survival of fish larvae is determined by the interplay of various environmental factors, such as temperature, food supply with a suite of species-specific characteristics [29]. The study results of water temperatures in three types of cages illustrated in figure 6. The average solar radiation was 429 (W/m²) and ambient temperature average was 27.4 °C on day time and 20.7 °C on night time also soil surface in lagoon temperature average was 26.2 °C on day time and 25.9 °C on night time, respectively. The average temperatures inside greenhouse fish cage and greenhouse fish cage was integrated with reduce heat loss system was 36.1°C, and 35.8 °C on day time and 23.2 °C, and 23.3 °C on night time, respectively.

From 120 days study period, normal fish cage (T-A), greenhouse fish cage (T-B) greenhouse fish cage was integrated with reduce heat loss system (T-C) were observed. The average water temperature was shown in difference between these three experiments including normal fish cage (T-A) 26.4 °C on day time and 26.2 °C on night time, greenhouse fish cage (T-B) 26.7 °C on day time and 26.4 °C on night time and greenhouse fish cage was integrated with reduce heat loss system (T-C) 27.6 °C on day time and 26.5 °C on night time, respectively (Figure 7). During growth period, most water parameters in three types of cages were in suitable ranges for fish growth. However the greenhouse with insulation fish cage integrated with reduce heat loss system (T-C) system expressed the better results, due to reasonable higher temperature which is favorable fish intake more. It could helpful to fish growth rate higher than others (T-A and T-B). Consequently, this study is recommended the greenhouse fish cage integrated with reduce heat loss system.

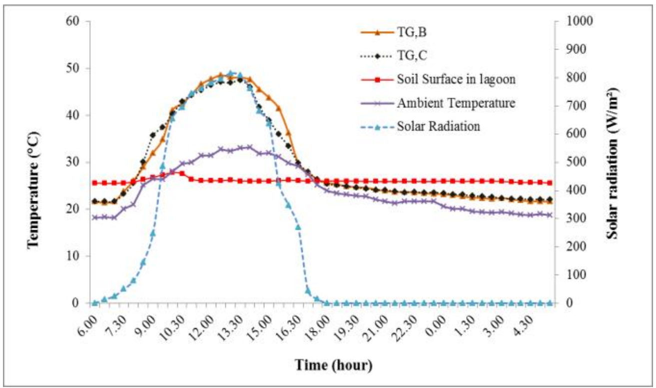

Figure 6. Temperatures in this study experiment cages. TG, B = Temperatures inside greenhouse fish cage and TG,C = Temperatures inside greenhouse fish cage was integrated with reduce heat loss system.

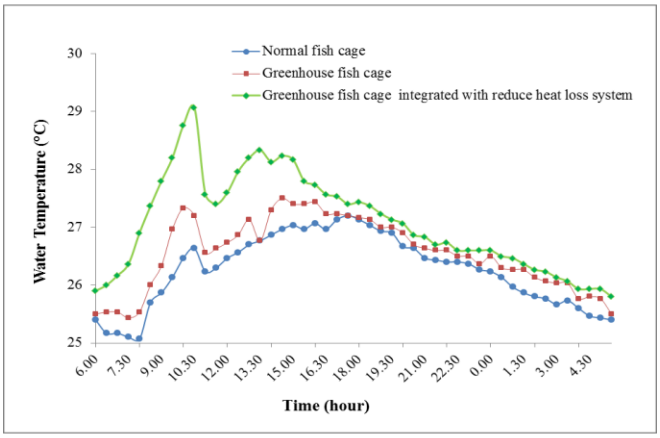

Figure 7. Water temperatures in this experimental study.

Adding water temperature suitable for the growth of the fish by using a greenhouse is the one of the best alternative. Water temperature attains maximum at 16:00 and minimum in the early morning 4:00 to 5:00 for greenhouse [30]. Water temperature can be maintained higher in greenhouse system [9],[10],[31]. In greenhouse systems, water is an excellent medium for the collection and storage of solar energy, thus an aquaculture system can function as a passive solar collector and heat stored in solar architecture [32]. From our study, It can be observed that inside greenhouse fish cage (T-B and T-C) air temperature higher than open condition (T-A). The rise in temperature due to greenhouse effect and reduced heat losses from greenhouse to ambient condition are responsible for the increase of greenhouse air temperature [26]. Water temperature inside greenhouse fish cage was integrated with reduce heat loss system (T-C) showed higher temperature than normal fish cage (T-A) and greenhouse fish cage (T-B). However, possible to using foam and covered with bamboo to reduce heat loss in system; and greenhouse system can provide the favorable water for fish farming during the winter season [33]. The water temperature is close to ideal water temperature for culture fish. Finally, additions of other technologies are might be assist in raising the water temperature further. Solar heating systems reduce conventional energy requirements for water heating in recirculation aquaculture systems [34]. Consequently, an excellent system could be display as resource recovery, energy conservation, reduces time for culturing fishes, water sparingly and maintenance of high water quality for active fish growth.

IV. CONCLUSIONS

The climbing perch (*Anabas testudineus*), is a highly priced air breathing, freshwater food fish species. They are also well known for their taste, high nutritive value, and recuperative and other medicinal qualities. Climbing perch is a much demanded fish in Thailand. In this study, mainly focused on temperatures on three types of cage systems namely (T-A) normal fish cage, (T-B) greenhouse fish cage and (T-C) greenhouse fish cage was integrated with reduce heat loss system were observed. Compared treatments (T-C) with treatments (T-A) and (T-B) results were presented an excellent growth over 15.65% and 6.13%, respectively. Therefore, using plastic film covering over ponds resulted in higher growth performance and lower production cost. Therefore, our study systems confirm that could be a promising method for farmers to culture the freshwater during the cold season. The study experimental results suggested that greenhouse through insulation fish cage integrated with hot air aerator could helpful for higher fish growth rate also helpful for fish farmers.

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