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# Changes in Condition Factor, Hepatosomatic and Gonadosomatic Index of Yellowfin Tuna (*Thunnus albacares*) in Captivity

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**ABSTRACT** The necessity for tuna products in the world community continues to increase, while production relies only on catching, thus causing overfishing. Therefore, breeding technology to support tuna farming is fundamental to be developed. Yellowfin tuna farming in Indonesia has been successful in cultivating broodstock. This paper discusses biometric data that changes during cultivation, such as condition factor, hepato and gonadosomatic indexes compared with wild captured. Data were collected from young tuna to broodstock and compared with wild captured such as fork length, body, liver and gonad weight. The condition factor (K) of cultivated tuna (1.5-2.5) was higher compared with wild captured (1.5-2.0). Similarly, the value of cultivated tuna's hepatosomatic index (HSI) was higher (0.63-1.14). In contrast, the gonadosomatic index (GSI) of wild captured yellowfin tuna was higher (>0.5) compared with cultivated yellowfin tuna in a circular concrete tank (0.4) but lower than that cultivated in a floating net cage (>1.4). Maintenance of broodstock in the tank with a lower GSI value means the number of eggs produced is relatively lower than its natural counterpart. At the same time, the high GSI value of cultivated broodstock in FNC shows better results than wild captured broodstock.

**Keywords:** Condition index; cultivation; yellowfin tuna

## INTRODUCTION

The level of exploitation of yellowfin tuna in each Fisheries Management Area (WPP) based on 2011 data was fully exploited (Anonymous, 2015[b]), and according to (Hartaty *et al*., 2019) yellowfin tuna population in the Indian Ocean was in the overfished (Hartaty *et al*., 2019), meaning that it is still possible to exploit but with the principle of prudence (Anonymous, 2015[b]). Among all tuna species traded by Indonesia, 72% are yellowfin tuna (Anonymous 2015[a]). The main fishing gear in the Eastern Atlantic Ocean was Tuna purse-seine, with an annual catch of more than 80 % (ICCAT, 2013) compared with other fishing gears. Data about yellowfin tuna above implied that the tuna population tends to decline and needs to develop a breeding program. Especially if the prediction of Anonymous (2021) that demand for yellowfin tuna is gaining popularity in the EU market and is expected to boost the growth over the 2020-2027 period.

Institute for Mariculture Research and Fisheries Extension (IMRAFE) has successfully developed the technology of catching young tuna Hutapea *et al*. (2003), fattened them to reach broodstock size and ready to produce eggs through the development of tuna cultivation in a controlled circular concrete tank and hereafter called CCT and has successfully produced seeds. Since 2013 fattening to reach broodstock size has been done in floating net cages and hereafter called FNC, near offshore waters.

Throughout the development of this yellowfin tuna cultivation and hatchery technology, some data and information have never been published. However, this information may be necessary, including condition factor, hepatosomatic index and gonadosomatic index of yellowfin tuna cultivated from young to broodstock size and throughout their productive life.

Condition factors (Rizzo & Bazzoli, 2020), hepatosomatic index and gonadosomatic index (Sardenne *et al*., 2016) can evaluate how a species or individual fish can utilize its environment. These parameters may also indicate physiological conditions based on fat accumulation, gonad development and adaptation to the environment (Effendi, 2002; Realino *et al*., 2010; Zudaire *et al*., 2014; Froese, 2016).

Specifically, the gonadosomatic index is a good indicator of reproductive activity, and this value for total spawning fish species is usually higher than partial spawning (Nunes *et al*., 2011). Hepatosomatic index values describe the role of the liver in the process of vitellogenesis. The condition factor is assumed to be isometric increases in body weight per unit of body length increase and has been used to indicate nutritional status and spawning activity (Deguara *et al*., 2013).

## MATERIALS AND METHODS

### *Data collections*

The data in this paper comes from the tuna maintenance data set in the circular concrete tank (CCT) from 2003 to 2008 and in FNC from 2013 to 2020. Procurement of yellowfin tuna is carried out by following the Hutapea *et al*. (2010[a]) procedure from the offshore North Bali Sea (Figure 1; 10-15 miles) by using hand line fishing (Hutapea *et al*., 2003) near the Fish Aggregating Devices (FAD). For each FAD visit, the coordinates were determined using GPS (GARMIN eTrex), which can be used as a guide to reaching the exact location on the next fishing day (Hutapea *et al*, 2010[a]).

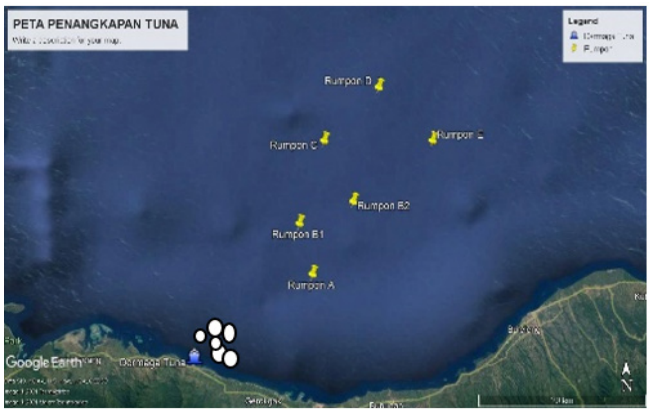


Figure 1. The fishing ground offshore of Northern Bali Sea (Yellow pin) and FNC (circles) is located near shore of IMRAFE facilities.

The size of the yellowfin tuna targeted was over one kilogram of body weight or fork length of more than 35 cm. The vehicle for live yellowfin tuna was Speed Boat with two outboard engines, each 85 HP. On the boat deck, equipped with one live tank. A rounded canvas tank of volume 2.5 $m^3$ (diameter 2.0 m and height 0.8 m) and on top of the tank was covered with a shading plastic. The other live tank was an oval fibreglass reinforced plastic tank with a volume of 2.1 $m^3$ (width 1.4 m, length 2.1 m and height 0.7 m) equipped with a lid. Seawater flowed from the top of the tank using a pump when the boat at stationary and with a pressure system while the boat was running. During transportation, oxygen was supplied into the water and kept at a 120-130 % saturation rate. After the tuna was caught and raised to the boat deck, a decision must be taken, tuna in good condition was immediately put into the transportation tank, but if too much wound and most likely could not survive, it was rejected and stored in a coolbox filled with bulk ice. Transportation took about 2-3 hours. Upon arrival, good fishes are put into tanks or cages, dead tuna at land-based facilities, measurements of fork length, body and liver weight, and gonad weight if it can be distinguished between males and females. This data was then used as primary data of wild captured. Yellowfin tuna were also purchased from local fishers to get big-size tuna's length and weight data. The total number of samples of captured dead yellowfin tuna purchased from local fishers was 250 fish.

### *Post-transportation*

Handling and maintenance of yellowfin tuna on land base facilities followed Hutapea *et al*. (2014) procedures. Healthy fish arrived at land-based facilities and was firstly acclimatized and immersed with anti-bacterial in a circular canvas tank. After treatment and the fish recovered, fork length measurement, inserted microchips tag in the dorsal muscle and then transferred fish into a tank of 8 m in diameter and 3 m in depth and cultivated to a size of 5-6 kg. Yellowfin tuna cultivation in FNC (Figure 1) also follows Hutapea *et al*. (2014), arrived young tuna captured then submerged with anti-bacterial, measurement of fork length and inserted the microchips tag carried out in the live transportation tank and then fish were replaced into FNC.

### *Cultivation, gonad maturation and spawning*

When young yellowfin tunas were put into the tank for cultivation, the initial size was between 26-64 cm with a bodyweight of 0.4-5.0 kg. Grown-to-be broodstock in-tank diameter of 18 m and a depth of 6 m followed Hutapea *et al*. (2010[b]), and the maximum number of tuna was 40 and replacement was carried out if there was a death of fish. The seawater used was from the nearshore connected through 2 pipes mounted on the seabed 250 meters to the well. Three pumps with a capacity of 7.5 HP with a discharge rate of 1 $m^3$/min are used to pump water from the well to the tower shelter after being through a high-pressure sand filter (HPF Model ASF-F2). Then the water is distributed to the research tanks troughs gravitationally.

Furthermore, water from the bottom of the tank was sucked by using 2 pumps with a capacity of 2.5 HP with a discharge rate of 0.4 $m^3$/min to the sand filter tank located higher than the tank and then water was flowed back through two PVC pipes of 8 inches in diameter to the rearing tank gravitationally. With this semi-closed circulatory system, daily water turnover was about 50% fresh seawater through a high-pressure sand filter and 50% water recirculation through a sand filter and then back into the rearing tank. To keep dissolved oxygen in the water always optimum, each tank was equipped with 3 aeration channels placed at the bottom of the tank and air was supplied through a blower (Mitsubishi, Type SF.HRCAO, 3.7 KW). Water quality management was carried out by measuring the temperature, pH and dissolved oxygen in the rearing tank daily and back-washed the high-pressure sand filter and the sand filter in the recirculation tank periodically. To clean the bottom of the tank, shiponing was done every 2 weeks by divers.

Maintenance of yellowfin tuna for fattening up to become a broodstock in the sea by using circular FNC with a diameter of 50 m and net depth of 9 m and a maximum number of tuna introduced were 135, and replacement was carried out if there was a death of fish. Periodically, technicians checked the nets by using diving equipment to ensure that the nets were in good condition and to estimate the number and size of tuna. In addition, net cleaning was carried out periodically so that the circulation of water into the net remains good and reduces the load of FNC due to the growth of biofouling.

Maintenance of candidate broodstock was carried out by feeding them with scad mackerel and squid with 5-10% of biomass per day with a ratio of 1:1. Feeding was carried out daily in the morning, except on Sunday. The fish were not fed to maintain a good tuna appetite for the following Monday. To improve health and to accelerate the gonad maturities, at each feeding was also added vitamin mix (40 g), which was a mixture of various vitamins, minerals and trace elements (*unpublished*) and vitamin C (7 g) daily and added vitamin E (14 g) daily in the irst and third week. Mix those three vitamins and then put them into capsules. Vitamin administration is based on the amount and biomass of the broodstock inserted into the feed.

Unlike other marine finfish, which can be sampled by catching and placing fish in a small container and then measuring or observing its gonad maturity. Yellowfin tuna

is a fast swimmer, very sensitive and without proper handling can end in death. Due to limitations of budget, so observations can only be made on dead fish but still in a good condition. To obtain biomeristic data, including the fork length, body, gonad and liver weight, yellowfin tuna were purchased from local fishers and data of dead tuna during the cultivation period both in CCT on land and FNC in the sea.

*Data analysis*

To standardize the measurement of biomeristic data, the fish samples were divided into size classes based on the fork length with a distance of every 5 cm. Those data were analyzed to obtain the condition index, namely the value of condition factor (K), hepato somatic index (HSI) and gonadosomatic index (GSI).

Condition factor was calculated by using formula K = 100 x W/ L3 (Bagenal, 1978) where, K= condition factor, W = total bodyweight (g), L = fork length (cm); Hepatosomatic index (HSI) by using formula HSI = LW (g)/BW (g) x 100, where, LW= liver weight and BW = total body weight; and Gonadosomatic index was calculated by using formula GSI = (gonad weight/ total body weight) x 100 (Shafi *et al*., 2012).

## RESULTS AND DISCUSSION

The maintenance of candidate broodstock of yellowfin tuna both in the tank and in FNC has been run well, and the samples used in this research only come from fish that die after a minimum of 60 days of cultivation. The number of samples obtained from the cultivated in-tank system was as many as 234 fish, and from FNC was 186 fish. Based on the fork length measurement, the yellowfin tuna samples in this study were less than 22 cm to 182 cm and were divided into 37 classes with a 5 cm distance between them.

Biomeristic data for captured tuna by fishers and cultivated tuna to become broodstock tanks was complete. While from cultivated tuna in FNC was challenging to get complete data because tuna died can be seen one or two days later, and the condition was swelled. From 186 total fish death during cultivation in FNC, only 8 fish can be used as samples, which were dead due to being hit into the net, but its body is still fresh and able to measure their biometric data.

The fork length (FL) of dead yellowfin tuna just after captured or during transportation was 18-79 cm with a bodyweight of 1.0-9.3 kg, while tuna purchased from local fishers in the Northern Bali Sea measured between 50-138 cm fork length and body weight of 2.0 - 49.0 kg.

Yellowfin tuna placed in the tank were grown to 36 -162 cm with a bodyweight of 0.9 -102.0 kg due to their different life span. While the tuna placed into FNC was between 21- 60 cm with a bodyweight of 0.2 - 4.0 kg and grown to 40 - 185 cm and 2.0 to more than 92.0 kg and of course with a different maintenance period.

*Condition factor (K)*

Based on observations and calculations, it was obtained that the value of the condition factors of captured yellowfin tuna samples ranged from 1.61 to 2.02, and there was a tendency that the value was relatively high in the fork length of 40-100 cm. On the other hand, cultivated yellowfin tuna in the tank showed condition factors ranging from 1.34-2.16 with a relatively high value in the fork length of 40-117 cm Furthermore, for yellowfin tuna cultivated in FNC, its condition factor values were 1.45-2.06 at a fork length of 83-182 cm (Figure 2). but the samples were only 8 fish found just after death and in good condition.

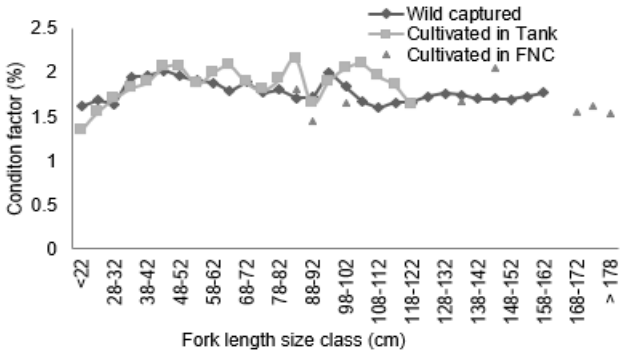


Figure 2. Factor condition pattern of yellowfin tuna (*Thunnus albacares*), captured, cultivated in circular concrete tanks and floating net cages.

Jatmiko *et al*. (2016) stated the value of the relative condition factor of yellowfin tuna landed in Benoa Harbour, the highest was 1.04 and found in the length group of 80 cm. Overall, the condition factor value of yellowfin tuna in this research was higher than the wild captured and cultivated in the tank and FNC. The difference in value is due to its different approach, i.e. using the comparison of the average body weight of the sample with the estimated weight based on the formula of the weight-length relationship (King, 2007). Furthermore, it is seen that the condition factor profile of yellowfin tuna samples from wild captured and cultivation in FNC was relatively stable while the cultivation in-tank tends to be similar to the results of Jatmiko *et al*. (2016), that the relative condition factor (Kn) tends to decrease with increasing of fork length and that a high relative condition factor is obtained in small yellowfin tuna. In this research, yellowfin tuna were cultivated in the tank and FNC. The condition factors were not much different between small and large yellowfin tuna. According to Froese (2006) and Effendie (2002), environmental conditions may also influence the condition factor. This was the case with cultivated yellowfin tuna, with regular and optimal feeding so that the condition factor was relatively stable and high. Zarrad (2014) also found that the bluefin tuna (*Thunnus thynnus*) condition factor under the fattened process increased.

On the other hand, Diaha *et al*. (2016) reported that the gonadosomatic and hepatosomatic index of Yellowfin tuna females increases as ovaries develop, but their condition factors remain stable. Compared to Salmon, the increased condition factor indicated the fish is in good condition, while the declined condition factor means low health condition (Barnham & Baxter, 1998). This means that the cultivated yellowfin tuna here was in good health condition.

*Hepatosomatic index (HSI)*

HSI values of captured yellowfin tuna range from 0.53-1.29 for a range of fork length 22-107 cm, cultivated in

the CCT were 0.37-1.79 for fish size 22-122 cm and from cultivated in FNC have a lower HSI value of 0.33-0.41 on fish sizes 83-92 cm (Figure 3). In general, the value of HSI of captured yellowfin tuna decreases with a fork length increase, while HSI of those cultivated in CCT tends to be fluctuative, and those cultivated in FNC were lower than wild captured cultivated yellowfin tuna in the tank. This difference may be due to the limited number of samples. One particular case was found on yellowfin tuna cultivated in the CCT on a size class 5 (fork length 38-42 cm), whose value was very different from others and still can not be explained and need observation of other factors. While yellowfin tuna is cultivated in FNC, because of limited samples or broodstock spawning continuously, the HSI value is low. Mardlijah & Patria (2012) found that the condition factor value of yellowfin tuna decreases during gonad maturation.

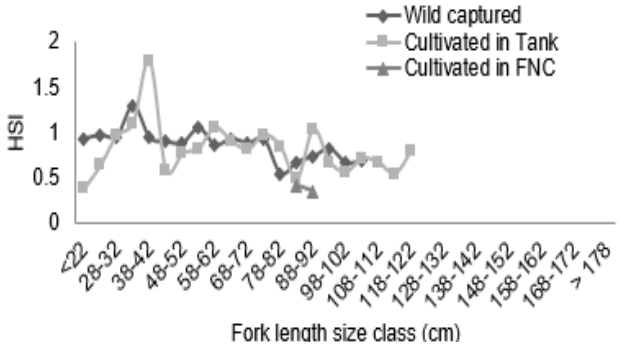


Figure 3. Pattern of Hepatosomatic index of yellowfin tuna (*Thunnus albacares*) population, captured, aptived in CCT and FNC.

*Gonadosomatic index (GSI)*

This research showed that gonads of yellowfin tuna were just seen at fork lengths of 48 cm and above. The GSI value of captured yellowfin tuna ranged from 0.03-0.67 in fork length 48-107 cm, slightly higher than thosec ultivated in the CCT which was 0.04-0.37 in fork length5 3-127 cm. Among reliable yellowfin tuna samples ultivated in FNC, its GSI value was 0.08-2.25 at a fork length of 83-172 cm (Figure 4) was the highest. In general, it was seen that the value of GSI increases when its fork length increase, but there was one data of yellowfin tuna cultivated in a CCT with a GSI value of 0.72 at a fork length range of 68-72 cm were much higher than other samples. No explanation for this value has been found. While yellowfin tuna cultivated in FNC, high GSI coincides with low HSI value, and this result follows the results of

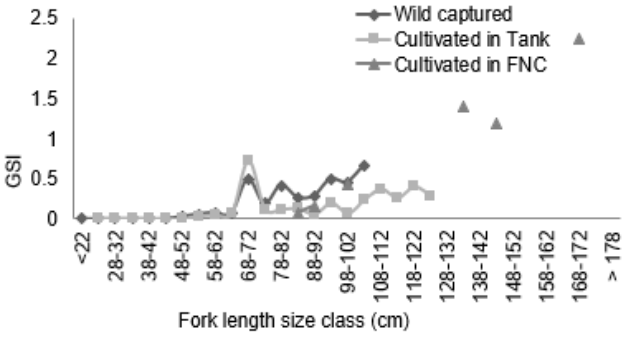


Figure 4. Gonadosomatic index pattern of yellowfin tuna (*Thunnus albacares*) captured and cultivated in the circular concrete tank and floating net cages.

Nunes *et al*. (2011) stated that HSI values are negatively correlated with GSI values.

The average gonadosomatic index (GSI) of yellowfin tuna captured in the Eastern Indian Ocean was 1.03 (0.11-7.81) Mardlijah & Patria (2012) and Arnenda *et al*. (2018) with a fork length of 66-158 cm obtained the average GSI value of 1.20-1.75, and Diaha *et al*. (2016), obtained in the Eastern Atlantic Ocean in November (2.08±0.52) to April (2.22±1.58) which was more than 1.5. This value was well above the GSI range in this research, both for wild captured and for those cultivated in the CCT. Only yellowfin tuna cultivated in FNC have a GSI value above previous reports. This suggests that cultivation in FNC is much better but in CCT tends to be less suitable for broodstock. With a high GSI value, the number of eggs that can produce per unit body weight of broodstock will be higher or more productive.

On the contrary, this report found that the broodstock cultivated in the CCT with a low GSI value, the number of eggs produced per unit of body weight was lower or less productive even though broodstock spawned throughout the year. Even, Mudumala *et al*. (2018) reported that GSI (0.04 to 0.573) of neritic tuna (*Thunnus tonggol*, *Euthynnus affinis* and *Auxis thazard*) were higher in spawning season. While broodstock cultivated both in concrete tanks and in FNC could spawn throughout the year or did not show the spawning season clearly, this may explain why the GSI was not high.

During the cultivation period of yellowfin tuna broodstock in CCT and FNC, water quality parameters measured are still within a suitable range for cultivation (Table 1). Notably, for cultivation in the CCT, if the level of dissolved oxygen saturation in the water was less than 82 %, a measurement of ammonia concentration should be done and if more than 0.20 ppm, then oxygen addition was carried out through the oxygen tube.

Table 1. The average value of water quality parameters in cultivating and maintaining yellowfin tuna broodstock (*Thunnus albacares*) in circular concrete tanks (CCT) and in floating net cages (FNC).

| Parameter | CCT | FNC |
|---|---|---|
| Temperature (°C) | 33.9±0.47 | 32.9±0.99 |
| Salinity (ppt) | 38.50±0.69 | 29.40±0.43 |
| Oxygen (ppm) | 5.30±0.12 | 7.03±0.65 |
| Saturation (%) | 84.14±2.14 | 94.9±5.76 |
| $NH_4$+(ppm) | 0.02-0.50 | - |

## CONCLUSIONS AND RECOMMENDATION

*Conclusions*

Cultivating young yellowfin tuna in a circular concrete tank (CCT) or a floating net cage (FNC) reached broodstock size and spawning continuously. Based on the condition index value (condition factor, hepato somatic and gonado-somatic index), young yellowfin tuna cultivated to become broodstock was better conducted in a floating net cage than in a circular concrete tank.

*Recommendation*

Further observations are needed for biomeristic data of yellowfin tuna cultivated in floating net cages to answer whether the actual HSI value is lower but the GSI value is higher than wild yellowfin tuna. Separate data processing between the female and the male broodstock for HSI and GSI values is needed to know if there is a difference in values or not.

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