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# METABOLIC RATES (SMR, RMR, AMR, AND MMR) OF *Oplegnathus fasciatus* ON DIFFERENT TEMPERATURE AND SALINITY SETTINGS

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**ABSTRACT**

The metabolic rate of aquatic animals is closely related to oxygen concentration and influenced by internal and external factors. Despite its high value as marine fish species in South Korea, information on rock bream *Oplegnathus fasciatus* metabolism is scarcely available. This study observed the standard metabolic rate (SMR), routine metabolic rate (RMR), and active metabolic rate (AMR) of rock bream *Oplegnathus fasciatus* subjected to different temperature settings. Another observation was performed to find out the maximum metabolic rate (MMR) on rock bream subjected to different salinity settings. Fish (TL: 26.86 ± 0.29 cm and BW: 469.40 ± 38.21 g for SMR, RMR, and AMR measurement; TL: 26.7 ± 0.4 cm and BW: 451.0 ± 44.4 g for MMR measurement) were observed using respirometer (dimension = 30 cm × 20 cm × 20 cm; volume: 10.4 L) inside a recirculation systems. SMR, RMR, and AMR were measured at 15°C, 20°C, and 25°C. Meanwhile, MMR was measured at 15, 25, and 35 psu. The results showed that SMR, RMR, and AMR increased linearly by increasing the temperatures (SMR: 58.7 ± 3.2, 102.7 ± 4.3, and 157.1 ± 4.1 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively; RMR: 66.0 ± 8.6, 112.6 ± 10.2, and 175.2 ± 21.3 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively; AMR: 73.4 ± 7.4, 122.0 ± 6.3, and 196.7 ± 15.4 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively), whilst MMR decreased by lowering salinity (48.5 ± 5.2, 61.1 ± 5.5, and 89.3 ± 14.7 mg $O_2$/kg/hour at salinity of 15, 25, and 35 psu, respectively).

**KEYWORDS: rock bream; *Oplegnathus fasciatus*; temperature; salinity; metabolic rates**

## INTRODUCTION

Oxygen is one of the limiting factors in aquaculture. Its effect is associated with fish metabolism which is currently regarded as one of the most studied physiological characteristics in animals (White *et al*., 2013). In addition, there are other variables affecting metabolism (Chabot *et al*., 2016; Rosewarne *et al*., 2016). Previous researches had been conducted to observe the effects of external factors on the metabolic rate of fish, such as temperature (Requena *et al*., 1997; Gillooly *et al*., 2001; Sarma *et al*., 2010), salinity (Iwama *et al*., 1997; Jeong *et al*., 2007; Prakoso *et al*., 2016), and stocking density (Bjornsson & Olafsdottir, 2006). Temperature and salinity have strong relationships with dissolved oxygen related to fish physiological response which could result in metabolic stress if the condition is not suitable (Mamun *et al*., 2013; Prakoso *et al*., 2015).

Rock bream *Oplegnathus fasciatus* is one of the important aquaculture species highly priced in South Korea. The fry of this species is cultured in hatcheries and released into the sea to maintain its sustainable stocks (Kim *et al*., 2008; Lipton & Kim, 2009). The geographic distribution of rock bream is within the region of Korea, Japan, Taiwan, and Hawaii in the North West and Eastern Central Pacific (Froese & Pauly, 2017).

Several types of metabolic rate are measured in previous studies such as standard metabolic rate (Halsey *et al*., 2015; Mamun *et al*., 2013), routine metabolic rate (Oh *et al*., 2006; Prakoso *et al*., 2015; 2016), active metabolic rate (Ohlberger *et al*., 2007; Mamun *et al*., 2013), and maximum metabolic rate (Norin & Clark, 2016; Killen *et al*., 2016). First, in his journal, J.R. Brett defined that "the standard metabolic rate is the minimum energy required for the fish to survive, associated with rest and unfed state" (Brett,

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1964). Second, F.E.J Fry noted in his journal that "the routine metabolic rate is the fraction of energy used by unfed fish with movement of spontaneous swimming or routine activity" (Fry, 1971). Third, the active metabolic rate is defined by T. Norin and H. Malte as "the metabolic rate during high level of activity at a given temperature, provides the upper boundary for aerobic energy metabolism" (Norin & Malte, 2011). Fourth, the maximum metabolic rate is described by T. Norin and T.D. Clark in their journal as "the maximum rate of oxygen consumption that a fish can achieve at a given temperature under any ecologically relevant circumstance" (Norin & Clark, 2016). However, the previous study on metabolic rates is still confined to other species. The limited knowledge on metabolic rates of rock bream is only available from a few study such as Oh *et al*. (2006); Yan *et al.* (2008); Ao (2015); and Prakoso *et al*. (2016). The information about metabolic rates could be applied to the fish aquaculture management. Therefore, in this study, we investigated standard metabolic rate (SMR), routine metabolic rate (RMR), active metabolic rate (AMR), and maximum metabolic rate (MMR) of individually reared rock bream subjected to different rearing temperature and salinity settings.

## MATERIALS AND METHODS

The study was conducted at the Laboratory of Fish Reproductive and Physiology at Pukyong National University, Busan, South Korea. The observation of metabolic rates on rock bream treated with different temperatures had been conducted in previous studies by Oh *et al*. (2006) and Ao (2015). However, these studies only measure the routine metabolic rate of fish. Furthermore, observation of fish metabolic rates in different salinity levels had also been conducted in other studies by Yan *et al*. (2008) and Ao (2015). However, both studies did not measure MMR. Based on those previous studies, this study aimed to obtain the information that has not been observed before. Rock bream (the total length: 26.86 ± 0.29 cm and total weight of 469.40 ± 38.21 g for SMR, RMR, and AMR measurement; the total length: 26.7 ± 0.4 cm and total weight: 451.0 ± 44.4 g for MMR measurement) were maintained within indoor recirculation system prior to the experiment. The fish were fed 2% of their body weight using commercial feed. The feed was given in the morning and evening (twice per day). One day before the experiment, fish were starved for 24 hours to avoid the influence of the feed to their metabolism. All experimental conditions in this study were described in Table 1.

Measurements using respirometer (dimensions: 30 cm × 20 cm × 20 cm; volume: 10.4 L) were conducted following the methods suggested by Chang *et al*. (2005). The data from the experiments were used to calculate the metabolic rates and $Q_{10}$ (the coefficient of factor where the reaction rate increases when the temperature is raised by 10 degrees). The coefficient $Q_{10}$ represents the degree of muscle dependence on the temperature measured by the level of contraction. If the reaction rate is completely independent to temperature, then the resulting $Q_{10}$ value is 1.0. It indicates muscle dependence to temperature. If the reaction rate increases with increasing temperature, the value of $Q_{10}$ will be greater than 1.0. An increase of $Q_{10}$ value indicates an increase in temperature dependence. Meanwhile, a value of $Q_{10}$ of less than 1.0 indicates negative temperature dependence, i.e. a decrease in muscle performance along with rising temperatures (Bennett, 1984). SMR, RMR, and AMR were taken as the lowest, average, and the highest oxygen consumption sustained for at least 1.5 hours by fish that had been undisturbed and unfed within 24 hours of observation (Fry, 1957; Beamish, 1964; Becker & Fishelson, 1990; Focken *et al*., 1994). Meanwhile, calculations and measurements of MMR performed in this study were adopted from the method conducted by Cutts *et al*. (2002). The maximum metabolic rate was measured by chasing the fish using a large scope net in the rearing tank for two minutes. After the fish exhausted, they were quickly inserted into the respirometer. During the measurement, a quick check was performed to make no air bubbles existed inside the respirometer. Measurements were performed for 15 times in each replication of MMR measurement to obtain the estimated MMR. During the experiment, photoperiod was set on the condition of 12 L : 12 D.

In this study, $Q_{10}$ values were calculated using the formula:

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{t_2 - t_1}\right)}$$

Where $R_1$ = metabolic rate at $t_1$ temperature, and $R_2$ = metabolic rate at $t_2$ temperature. For temperature treatments, $Q_{10}$ values were collected by rearing the fish at 32 psu with different temperature settings (15°C, 20°C, and 25°C). Meanwhile, for salinity treatments, $Q_{10}$ values were collected by rearing the fish at three different salinity levels (15, 25, and 35 psu) with different temperatures (15°C, 20°C, and

Table 1. Experimental conditions during observation of metabolic rates on rock bream *Oplegnathus fasciatus*

| Experiment | | Salinity (psu) | Water temperature (°C) | Fish number (individu) | Replication |
|---|---|---|---|---|---|
| Measuring SMR, RMR, and AMR | 1 | 32 | 15 | 1 | 3 |
| | 2 | 32 | 20 | 1 | 3 |
| | 3 | 32 | 25 | 1 | 3 |
| Measuring MMR | 1 | 35 | 15 | 1 | 3 |
| | 2 | 25 | 15 | 1 | 3 |
| | 3 | 15 | 15 | 1 | 3 |

Description: SMR = standard metabolic rate, RMR = routine metabolic rate, AMR = active metabolic rate, MMR = maximum metabolic rate

25°C). Data were analyzed by one-way ANOVA using statistical software PASW Statistics 18.

## RESULTS AND DISCUSSION

Temperature affects all biochemical reactions in the body and has a significant impact on the physiology of the organism. Therefore, research on the tolerance to temperature and its effect on fish health is important to be observed. As shown in Table 2, the values of SMR, RMR, and AMR showed significant difference based on three different temperature levels ($P < 0.05$). The SMR values increased significantly with the increase in temperature (58.7 ± 3.2, 102.7 ± 4.3, and 157.1 ± 4.1 mg O2/kg/h at 15°C, 20°C, and 25°C, respectively), whilst the lowest values of RMR and AMR of rock bream were found at 15°C (66.0 ± 8.6 and 73.4 ± 7.4 mg $O_2$/kg/h, respectively) compared with the value of RMR and AMR observed at 20°C (112.6 ± 10.2 and 122.0 ± 6.3 mg $O_2$/kg/h, respectively) and 25°C (175.2 ± 21.3 and 196.7 ± 15.4 mg $O_2$/kg/h, respectively).

The process of metabolism in fish usually has a positive correlation with temperature. This is due to the Van't Hoff effect, where the rate of biochemical reactions increases exponentially with temperature (Marshall & McQuaid, 2011; Branch & Newell, 1978). Higher temperatures increase the proportion of enzymes that have reached their activation energy levels, which accelerate the average rate of biochemical reactions to allow for more activity (Houlihan & Innes, 1984) and require more oxygen (Bartholomew & Casey, 1977). Therefore, the metabolic rate of an ectothermic animal is closely related to temperature, because the temperature regulates routine metabolic rate (RMR) and indirectly triggers active metabolic rate (AMR).

In this study, the metabolic rates of rock bream were affected by temperature increase. These results are consistent with the studies using different fish species which reported that the oxygen demand of the fish increased linearly with temperature increase (Gardner & King, 1922; Chang *et al*., 2005; Oh *et al*., 2006). Both behavioral and physiological factors can influence how temperature affects the activity level and metabolic rate of ectothermic animals. From the perspective of behavior, for example, at a temperature where the chance is high to get food, animals can increase their activity level to maximize energy

Table 2. Metabolic rates of rock bream *Oplegnathus fasciatus* measured at different temperatures

| Temperature (°C) | Metabolic rate (mg $O_2$/kg/h) | | |
|---|---|---|---|
| | SMR | RMR | AMR |
| 15 | 58.7 ± 3.2$^c$ | 66.0 ± 8.6$^c$ | 73.4 ± 7.4$^c$ |
| 20 | 102.7 ± 4.3$^b$ | 112.6 ± 10.2$^b$ | 122.0 ± 6.3$^b$ |
| 25 | 157.1 ± 4.1$^a$ | 175.2 ± 21.3$^a$ | 196.7 ± 15.4$^a$ |

Description: SMR = standard metabolic rate, RMR = routine metabolic rate, AMR = active metabolic rate. Different superscripts in a column indicate significant difference among treatments ($P < 0.05$)

intake (Speakman, 1986). Alternatively, they may be less active due to, for example, there are many predators (Anholt *et al*., 2000; Werner & Anholt, 1993). In terms of the physiological perspective, there is a direct effect of temperature on biochemical reactions involved in the movement (Halsey *et al*., 2015).

As shown in Table 3, salinity changes have a significant impact on fish metabolism. In this study, the mean values of MMR in rock bream were 48.5 ± 5.2, 61.1 ± 5.5, and 89.3 ± 14.7 mg $O_2$/kg/h, respectively on 15, 25, and 35 psu. The values showed significant differences based on salinity treatment ($P<0.05$).

MMR of rock bream in each treatment showed significant differences related to different salinity settings ($P<0.05$). The results showed the tendency of MMR in rock bream decreasing in line with lowering salinity level. The lowest value of MMR was found at 15 psu. MMR of rock bream at 25 and 15 psu each was 54.3% and 68.4% lower than MMR at 35 psu. This phenomenon is in accordance with the opinion of Morgan & Iwama (1991) who argued that salinity is closely related to low metabolic rate. In this study, the results show that in the low-salinity environment, the activity level of rock bream had lowered. The results of this study were also similar to the findings of Jeong *et al*. (2007) observing *Acanthopagrus schelgelii* and Prakoso *et al*. (2015) studying *Mugil cephalus*. These studies found that the metabolic rates of fish reared in freshwater were lower than those of seawater. The declining of MMR is due to the effect of reduced gill permeability to prevent water intrusion and ion loss in gill epithelium. A similar effect of salinity change on MMR also applies to freshwater fish. The reduction in gill permeability will occur to reduce osmotic stress (Gonzalez & McDonald, 1992). This indicates an interaction between salinity and aerobic performance of rock bream.

The $Q_{10}$ value for SMR between 15°C and 20°C (3.1) was higher than those of SMR at 20°C-25°C (2.3). The $Q_{10}$ value calculated from RMR at 15°C-20°C was higher (2.9) than those calculated from RMR at 20°C-25°C (2.4) and 15°C-25°C (2.7). Meanwhile, the $Q_{10}$ value calculated from AMR at 20°C-25°C was higher (3.1) compared with the values calculated from AMR at 15–20°C (2.7) and 15°C-25°C (2.7). The lowest $Q_{10}$ values were found from the calculation of SMR and RMR values at 20°C-25°C (2.3 and 2.4, respectively) (Table 4). Moreover, based on different salinity settings, the highest average $Q_{10}$ was found in the temperature range of 15°C-20°C at salinity of 15 psu, with a value of 10.2, while the lowest average value of $Q_{10}$ was obtained in the temperature setting of 20°C-25°C at salinity of 15 psu with a value of 2.5 (Table 5).

A similar increase in SMR with the increase in temperature was also observed in this study. The effect of temperature on SMR was evident by looking at the increase of $Q_{10}$ values when temperature was increased from 15°C to 20°C ($Q_{10}$ = 3.1) than 20°C to 25°C ($Q_{10}$ = 2.3) and 15°C to 25°C ($Q_{10}$ = 2.7). A similar effect of temperature on SMR was also observed in goldfish (Beamish & Mookherjii, 1964) and black porgy (Jeong *et al*., 2007). Temperature has a significant effect on the speed and strength of muscle contraction of living things. In general, muscle performance decreases with decreased temperature and increases with increasing temperature.

In most biological processes, especially those involving large-scale protein conformation changes, the value of $Q_{10}$ is greater than two, or in the range of 2 to 3 (Reyes *et al*., 2008). A decrease in temperature in muscle causes a significant decrease in muscle performance in which a 10°C temperature drop resulting in at least 50% reduction in muscle performance (Deban & Lappin, 2011). In vertebrates, different muscle activities have different dependences on temperature. The degree of muscle contraction and relaxation depends on temperature ($Q_{10}$ = 2.0-2.5), whereas the maximum contraction is independent of

Table 3. Average value of maximum metabolic rate on rock bream *Oplegnathus fasciatus* treated in different salinity levels at 15°C rearing temperature

| Salinity (psu) | MMR (mg $O_2$/kg/h) |
|---|---|
| 15 | 48.5 ± 5.2$^c$ |
| 25 | 61.1 ± 5.5$^b$ |
| 35 | 89.3 ± 14.7$^a$ |

Description: MMR = maximum metabolic rate; each values represent means ± SD (n=15). Different superscript letters in the same column indicate significant differences ($P<0.05$)

Table 4. $Q_{10}$ values of different metabolic rates on rock bream *Oplegnathus fasciatus* measured at 15°C to 25°C

| Metabolic rates | Temperature range (°C) | | |
|---|---|---|---|
| | 15-20 | 20-25 | 15-25 |
| SMR | 3.1 | 2.3 | 2.7 |
| RMR | 2.9 | 2.4 | 2.7 |
| AMR | 2.8 | 3.1 | 2.7 |

Description: SMR = standard metabolic rate, RMR = routine metabolic rate, AMR = active metabolic rate

Table 5. Average $Q_{10}$ values of rock bream *Oplegnathus fasciatus* on three different salinity levels measured at 15°C to 25°C

| Temperature range (°C) | $Q_{10}$ value | | |
|---|---|---|---|
| | 15 psu | 25 psu | 35 psu |
| 15-20 | 10.2 | 4.5 | 2.6 |
| 20-25 | 2.5 | 3.4 | 3.0 |
| 15-25 | 4.8 | 3.9 | 2.7 |

temperature (Bennett, 1985). Therefore, the value of $Q_{10}$ can be used to describe the physiological processes of the object under investigation. The results from the present study indicated that temperature variation between 15°C and 20°C was within suitable range for rock bream to maintain their maximum metabolic efficiency. Furthermore, this study found that salinity rearing at 15 psu on temperature range from 15°C to 20°C has the highest reaction rate to maintain the metabolism efficiency for rock bream. Hence, important metabolic rates information of rock bream discussed in this paper might provide valuable information for commercial aquaculturists to ensure sustainable aquaculture management practice. Specifically, the scientific knowledge on the metabolic performance of rock bream under different environmental conditions is very important to enhance their growth and survival.

## CONCLUSION

The results showed the tendency of metabolic rates of rock bream *Oplegnathus fasciatus* increased linearly with the increased in temperature; with the standard metabolic rate (SMR), routine metabolic rate (RMR), and active metabolic rate (AMR) were significantly higher at higher temperatures (SMR: 58.7 ± 3.2, 102.7 ± 4.3, and 157.1 ± 4.1 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively; RMR: 66.0 ± 8.6, 112.6 ± 10.2, and 175.2 ± 21.3 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively; AMR: 73.4 ± 7.4, 122.0 ± 6.3, and 196.7 ± 15.4 mg $O_2$/kg/h at 15°C, 20°C, and 25°C, respectively).

The value of the maximum metabolic rate (MMR) of rock bream was also decreased with lowered salinity. The results from this present study on $Q_{10}$ values indicated that the range from 15°C and 20°C was within acceptable value for rock bream to maintain their maximum metabolic efficiency. Meanwhile, the value of $Q_{10}$ indicates that salinity of 15 psu is the highest point on reaction rate to temperature increase for rock bream compared with 25 and 35 psu. Further research is needed to study the lethal dissolved oxygen level for rock bream reared under certain temperature levels.

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