Metabolic rate of *Cherax quadricarinatus*

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Abstract: Temperature is the most prominent factor that influence metabolic rate of aquatic animals. In general, the increasing temperature of 10 degrees Celsius will improve metabolic rate two-fold. Therefore, this research aim is to examine the metabolic rate and Q_{10} value of crayfish. The metabolic rate of crayfish (*Cherax quadricarinatus*) was examined by determining oxygen consumption rates using caulorimetric respirometer. The oxygen consumption rates of *Cherax quadricarinatus* which acclimated at 23°C and 31°C is at around 0.52 and 0.7 uL/g/min respectively. Furthermore, the Q_{10} value of crayfish between 23°C and 31°C is 1.47. The oxygen consumption and Q_{10} value of crayfish is different compare with other aquatic invertebrate and ectotherms.

Keywords: *Cherax quadricarinatus*, metabolic rate, temperature, oxygen

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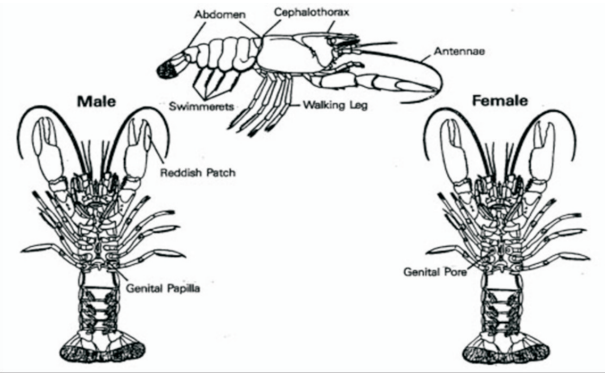
1 INTRODUCTION

The uptake of oxygen and release of carbon dioxide constitute respiration that applies both to the whole organism and to the processes in the cells [1]. The respiration between animals with aerobic metabolism and their environment is linked to the rate of oxidative metabolism in the tissues. Aquatic animals take up oxygen from the small amounts of this gas dissolved in water through special respiratory organ (gills) [2]. The eminent physical process in the movement of oxygen from the water to the cell is diffusion. The amount of gas dissolved in water depends on the pressure of the gas. If the gas pressure is doubled, twice as much gas will be dissolve. On the other hand, the solubility of gases declines with increasing temperature [1]. The availability of oxygen can be reduced in the aquatic environment, particularly in stagnant water, where bacterial action can cause a reduction in dissolved O_2 of the water (hypoxia). During a progressive reduction in oxygen tension over a period of a few hours, an aquatic animal may allow it to fall (conform) or maintain its oxygen uptake (regulate) [3].

Rate of oxygen consumption is influenced by activity, temperature, body size, stage in life, season, and time of day. When the dissolved oxygen declines, the ventilatory volume increases markedly, breathing rate rise slightly, stroke volume of the heart improve much and heart rate is reduced [2]. For instance, in fish, if temperature is raised, ventilation volume increases first and rate later but at a critical temperature, heart rate slows with inadequate oxygenation. In addition, when oxygen dropped from 6.6 to 2.1 ml/L, the crayfish tripled the breathing rate and doubled the ventilation volume [1]. Crayfish *Cherax quadricarinatus* (Figure 1) is adapted to living in warm climate that experiences seasonal fluctuations environmental conditions. They can tolerate exposure to anoxic and hypoxic environments, including any metabolic adjustments which allow its survival [4].



Gambar 1: Female and male of crayfish Cherax quadricarinatus [5]

Some of the ways to examine metabolic rate of aquatic animal is to measure its oxygen consumption rate by respirometric and calorimetry measurements [6]. Respirometric measurements examine just the aerobic metabolic rate of the aquatic animals. While, calorimetry is used to measure the contribution of anaerobic and aerobic pathways to the total metabolism of aquatic animal [3]. Furthermore, by in-

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direct calorimetry, we can determine the rate of oxygen consumption and then calculate the rate of energy expenditure from the caloric equivalent of oxygen. The metabolism of ectotermic aquatic animal increases and decreases with body temperature by about two and one-half times per 10°C in the physiology range [1].

Therefore, the objectives of this study are, first, to determine oxygen consumption of *Cherax quadricarinatus* in upper and lower temperature, and compared that with other invertebrate aquatic animals. The second aim is to determine the difference in respiration rates over a 10oC interval (Q_{10}) of crayfish and compared that with other aquatic ectotherms.

2 MATERIAL AND METHOD

Firstly, respirometer chamber which the crayfish inside was placed in a bin containing freshwater in order to facilitate the removal of trapped air from the system. The head of respirometer had an opening for insertion of oxygen electrode and two pipes which were connected to a pump for circulating water through the respiration chamber. The exhaust pipe was directed downward for maximum circulation of water within the chamber; while, the intake pipe was ended just under the side of the electrode membrane, in order to draw water across it. The chamber also had a small hole fitted with a rubber stopper for insertion of a thermometer and for removal of water when the respirometer was not in operation. The entire system allowed the temperature of water inside the respirometer to be maintained. The oxygen electrode was connected through a circuit which allowed continuous monitoring of oxygen concentration in the respirometer.

After that, the software program for measuring respiration was installed in computer. The polarographic electrode system, which connected to the software computer, was calibrated for air saturation level of oxygen concentration by putting the DO probe tip in sodium sulfite calibration solution. In software program, sensor setting was clicked to enter value data unit 8.44 mg/L (look table 740 mm DO 8.44 mg/L) for 23°C in the first and for 31°C in the next experiment. Temperature was changed by adjust the heat flux. These temperatures encompass the normal temperature range to which crayfish is subjected in nature. Then, probe was inserted into chamber and data was collected three times (replicate) in each temperature for 15-minute cycle that sampled every 0.05 seconds.

The oxygen metabolic rate of crayfish was measured while the animal remained motionless (passive) was assumed to represent resting metabolism. The water in the respirometer chamber that around 1500mls was replaced before each run by opening the pipe to circulate the water and aerating until air saturated. Circulating water was controlled by opening two valves to let water in and out and these valves were shut when the experiment was conducted. The DO levels were recorded on a computer using Loggerpro 6.1 software. Finally, from the data, the rate of oxygen consumption and the difference in respiration rates over a 10°C interval (Q_{10}) of crayfish was calculated. The resultant oxygen consumption value was divided by the weight of the crayfish, which is 103 gram, to obtain the weight specific oxygen consumption in ul.g.minute for each DO. In order to examine Q_{10}, standard linear regression analyses were made on these variables.

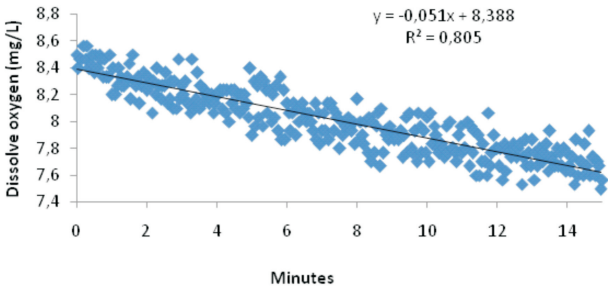
Q_{10} can be rtepresented by the following expression:

$$Q_{10} = \left\{ \frac{K_2}{K_1} \right\} \frac{10}{(t2/t1)}$$

where t_2 = higher temperature $k_2 = O_2$ consumption rate at t_2; and t_1 = lower temperature $k_1 = O_2$ consumption rate at t_1

3 RESULTS

As can be seen from the figure 2, the dissolve oxygen (DO) for crayfish that placed in respirometer chamber in 23 °C decreased during 15-minute with the slope at around 0.051. Furthermore, from the regression line the DO started at about 8.4 mg/L and ended at approximately 7.6 mg/L with the standard deviation at 0.08 (table 1).

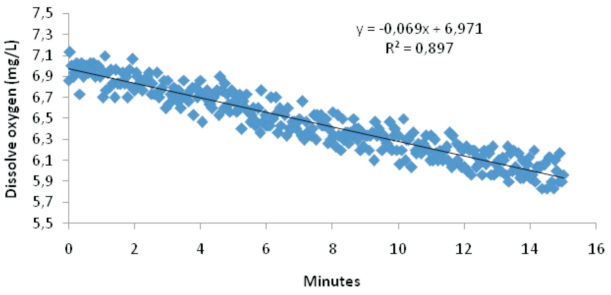


Gambar 2: The linear regression line for dissolve oxygen over 15-minute in crayfish that placed in respirometer chamber and acclimated in 23°C.

Similarly, from the figure 3, it clearly show that the dissolve oxygen (DO) for crayfish that placed in respirometer chamber in 31 °C declined during the experiment with the slope at around 0.07. In addition, from the regression line, the DO started at about 6.9 mg/L and ended at 5.9 mg/L with the standard deviation at 0.08. Moreover, from the calculation, the oxygen consumption of crayfish that acclimated in 23 °C with at around 0.52 uL/g/min is lower compared to that in 31 °C with at 0.7 uL.g-1.min-1. However, the Q_{10} calculation for both 23 °C and 31 °C is the same with at 1.47 (table 1).

Tabel 1: The dissolve oxygen started and ended, linear regression slope, oxygen consumption and Q_{10} from crayfish which acclimated in 23°C and 31°C for 15 minute.

Temperature (celcius)	DO started (mg/L)	DO ended (mg/L)	Slope	Oxygen consumption (uL.g^{-1}.min^{-1})	Q_{10}
23	8.4	7.6	0.05	0.52	1.47
31	6.9	5.9	0.07	0.70	1.47



Gambar 3: The linear regression line for dissolve oxygen over 15-minute in crayfish that placed in respirometer chamber and acclimated in 31°C.

4 DISCUSSIONS

The rate of oxygen consumption of *Cherax quadricarinatus* at rest condition at the lower temperatures and at the upper temperatures is different. At rest condition, respiratory gas exchange and transport are matched to the metabolic rate[3]. The oxygen consumption at upper temperatures is higher than at lower temperatures. It occurs because all chemical reactions in crayfish body are accelerated by an increase in temperature. The changing of surrounding water temperature influence ectotermic animal's metabolic processes and induce response that include change in the metabolic enzymes and tissues chemistry which are suggested to mitigate the effect of temperature on metabolism. According to Meade et al[4], temperature is the major variable affecting oxygen consumption rates in *Cherax quadricarinatus* rather than water quality, oxygen availability and nutrition. Likewise, in catfish (H. brachysoma), their oxygen consumption rate also increase with increasing acclimation temperatures. In ectotermic animal, the metabolic responses that are quantified in terms of oxygen consumption show a linear correlation to temperature because of its direct effect on the kinetics of the enzyme reactions involved[7]. According to Meade et al[3], *Cherax quadricarinatus* are oxygen regulator and can compensate metabolically via anaerobic/aerobic adjustments to maintain metabolic rate at low dissolve oxygen.

From the result, the oxygen consumption in *Cherax quadricarinatus* at 23°C and 31°C is 0.52 and 0.70 uL/g/min respectively. The oxygen consumption compare with other aquatic invertebrates is different. It occurs because every aquatic invertebrate have their own way to deal with dissolve oxygen availability[8]. As can be seen from table 2, for example in the spiny lobster, Panulirus Interruptus, the oxygen consumption from them (124.3-155.5 g) in 20°C is around 0.08 uL/g/min which is greater than the oxygen consumption in *Cherax quadricarinatus*. Similarly, from table 3, the oxygen consumption from decapod crustacean such as *Panulirus interuptus, Orconecctes immunis, Carcinus maenas* and *Ocypode quadrata* is higher than in Cherax quadricarinatus[8].

Crayfish (*Cherax quadricarinatus*) with acclimated at 23 oC and 31°C have Q_{10} value at 1.47. A Q_{10} of 1.47 suggests that raising the temperature of their surrounding environment by 10°C will effectively increase the metabolic rate of 1.47 times. The Q_{10} value is useful to suggest whether or not the metabolic rate being examined is controlled by temperature or by some other factor. As a general rule reaction rates double for each increase of 10 degrees Celsius[1]. From the practical result, it can be taken hypothesize that some factor other than temperature is controlling the metabolism in *Cherax quadricarinatus*. The other aquatic animal such as catfish (Horabagrus brachysoma) which was acclimated for 30 days at temperature between 15-20°C have Q_{10} value at 2.59, while, between 31-33°C have Q_{10} value at 1.53[7]. Therefore, the Q_{10} of crayfish is higher than catfish and it can be assumed that crayfish has better capability for adapting to higher temperatures.

5 CONCLUSION

The rate of oxygen consumption of *Cherax quadricarinatus* at rest condition at the lower temperatures and at the upper temperatures is different. Moreover, the oxygen consumption at upper temperatures is higher than at lower temperatures. The oxygen consumption and Q_{10} value of crayfish is different compare with other aquatic invertebrate and ectotherms.

DAFTAR PUSTAKA

[1] Prosser, C. L. 1973. Oxygen: respiration and metabolism. Pages 170-199 *in* C. L. Prosser, editor. Comparative animal physiology. W. B. Saunders Company, London.

[2] Graham, J. B. 2006. Aquatic and aerial respiration. Pages

TABEL 2: Weight-specific oxygen uptake in P. interruptus during resting metabolism in ml/g/hr or uL/g/min [8]

Wet body weight (g)	Mean QO_2 from 6.5–2.5 ppm	Mean temperature of experiment (°C)	Wet body weight (g)	Mean QO_2 from 5.5–2.5 ppm	Mean temperature of experiment (°C)	Wet body weight (g)	Mean QO_2 from 5.0–2.5 ppm	Mean temperature of experiment (°C)
56.0	0.0766	12.8	216.4	0.0435	16.0	124.3	0.0822	19.8
100.8	0.0585	12.9	245.0	0.0544	15.9	155.5	0.0876	19.9
214.0	0.0498	12.5	250.0	0.0377	15.9	171.0	0.0658	19.9
233.8	0.0297	13.3	302.0	0.0521	16.0	204.7	0.0629	19.8
243.5	0.0396	12.5	335.4	0.0539	16.1	227.1	0.0663	19.8
279.4	0.0207	12.9	354.5	0.0439	15.9	255.9	0.0758	19.8
293.9	0.0348	13.0	364.5	0.0568	15.9	372.6	0.0654	19.6
328.4	0.0296	12.6	366.6	0.0521	15.5	379.4	0.0578	19.7
342.7	0.0319	13.0	420.7	0.0435	16.0	387.9	0.0648	19.8
393.6	0.0351	12.6	429.9	0.0492	16.0			
			524.3	0.0492	16.0			
			578.7	0.0429	15.9			

TABEL 3: Oxygen consumption in ml/g/hr or ul/g/minute in decapod crustaceans [8,9,10]

Species	Wet body weight (g)	Temperature (°C)	QO_2 (ml/g/hr)	Reference
Macrura				
Scyllaridae				
Palinurus elephas	—	15	0.044	Wolvekamp and Waterman (1960)
Panulirus interruptus	200–600	13	0.034	This study
		15	0.048	
		16	0.048	
		20	0.066	
P. argus	300	30	0.091**	Maynard (1960)
Nephropsidae				
Homarus americanus	189	15	0.035	Thomas (1954)
	230	22	0.037	
	324	22	0.039	
H. vulgaris	400*	15	0.063*	Thomas (1954)
	680*	15	0.040*	
H. gammarus	—	15	0.068	Wolvekamp and Waterman (1960)
Orconectes immunis	—	25	0.160–0.170	Wolvekamp and Waterman (1960)
Brachyura				
Carcinus maenas	—	16	0.052–0.071	Wolvekamp and Waterman (1960)
Cancer pagurus	—	16	0.107	
Ocypode quadrata	—	26	0.196	
Pugettia producta	—	15	0.032–0.170	
Mean of 54 crustaceans	—	15	0.108	Wolvekamp and Waterman (1960)

* Values approximated from graphs (Thomas, 1954).
** Calculated from formula $QO_2 = 0.24W^{-0.17}$ (Maynard, 1960).

85-99 in D. H. Evans and J. B. Claiborne, editors. The physiology of fishes. CRC Press, New York.

[3] Meade, M. E., J. E. Doeller, D. W. Kraus, and S. A. Watts. 1994. Heat and oxygen flux as a function of environmental PO2 in juvenile Australian crayfish, (*Cherax quadricarinatus*). Journal of Experimental Zoology 270:460-466.

[4] Meade, M. E., J. E. Doeller, D. Kraus, and S. A. Watts. 2002. Effects of Temperature and Salinity on Weight Gain, Oxygen Consumption Rate, and Growth Efficiency in Juvenile Red-Claw Crayfish (*Cherax quadricarinatus*). Journal of the World Aquaculture Society 33:188-198.

[5] Masser, M.P. and Rouse, D.B., 1997. Australian Red Claw Crayfish Southern Regional Aquaculture Centre Publication No. 244

[6] Maynard, D. M. 1960. Heart rate and body size in the spiny lobster. Physiol. Zool., 33: 241-251

[7] Dalvi, R.S., Pal, A.K., Tiwari, L.R., Das, T., Baruah, K., 2009. Thermal tolerance and oxygen consumption rates of the catfish *Horabagrus brachysoma* (Gnther) acclimated to different temperatures. Aquaculture 295, 116-119.

[8] Winget, R.R., 1969. Oxygen consumption and respiratory energetics in the spiny lobster, *Panulirus Interruptus* (Randal). Biol. Bull 136:301-312.

[9] Thomas, H. J. 1954. The oxygen uptake of the lobster, *Homarus vulgaris* (Edw.) J. Exp. Biol., 31 : 228-251

[10] Wolvekamp, H. P., and T. H. Waterman. 1960. Respiration, p. 35-100. In T. H. Waterman, Ed., The Physiology of Crustacea, Vol I. Academic Press, New York.