Aerobic Poise of Marine Fish in Relation to Habitat and Lifestyle

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Abstract: Fish from different species have different way to deal with their lifestyle and habitat. From four species that have been researched, *Pseudocaranx dentex* and *Scomberomorus munroi* have higher proportion of red muscle, higher relative gill and higher ventricular mass also their muscle have higher buffering capacity than *Lethrinus miniatus* and *Lutjanus erythropterus*. It also has been found that white muscle has better ability to handle acid than red muscle. The red muscle are involved in the aerobic slow swimming, while the white muscle have role in faster or burst swimming (anaerobic energy pathway). Therefore, *Lethrinus miniatus* and Lutjanus erythropterus are less active fish than *Pseudocaranx dentex* and *Scomberomorus munroi*.

Keywords: fish, white muscle, red muscle, buffering capacity

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1 INTRODUCTION

Fish are the only group of vertebrates that show anatomical separation of the different muscle type. Fish muscle performs function associated with digestion, secretion, reproduction, locomotion, etc. The speed of locomotion and from here its ability to escape from predator and to catch prey, is limited by the reaction of its muscles[1]. There are two type of muscle in fish which are red and white muscle (although intermediate types do occur, e.g. pink muscle of salmonids) [2]. Red muscle is often referred to as slow oxidative muscle and is used for sustained aerobic activity, it has high mitochondrial densities, extensive capillary networks, high myoglobin content and operates aerobically[3]. Myoglobin is an oxygen binding protein that gives red muscle its characteristic colour. White muscle is often referred to as fast glycolytic muscle and usually shows converse traits, it is has low mitochondrial myoglobin content and may operate anaerobically during short bursts of fast swimming[4].

Therefore, the requirement of oxygen is depend on the fish activities, habitat and lifestyle. In very active fish, the total gross gill area is larger than in inactive and fast-swimming fish pretend to do ram ventilation to provide maximum water flow over the gills[5]. In addition, with increase in activity, hearts as a circulatory system have responded to provide blood in adequate amount to deliver oxygen[6]. Therefore, this study aims to estimate the relative proportion of red muscle along the body of four species, the swimming lifestyle of the fish and its scope for aerobic activity.

2 MATERIALS AND METHODS

This study was divided into three sections and used four fish species (*Lethrinus miniatus*, *Scomberomorus munroi*, *Pseudocaranx dentex*, *Lutjanus erythropterus*) for the experiment.

2.1 Scope for aerobic activity

Firstly, excess water from the fish was removed before recorded the fork length, maximum girth and position along the body, and fish weight. After that, operculum was lifted and the gills were examined also the diagram arrangement of gills filament was made. To estimate gill efficiency, the gills was removed and the ratio of filament weight to total body weight was obtained. The pericardium was opened and the heart was removed to made comparison between different species. The heart was drained from any remaining fluid with saline water and the ventricle was removed. Furthermore, ventricle weight was measured and relative ventricular mass was calculated.

2.2 Proportion and location of red muscle

Five cross-sections around 10mm thick from behind the pectoral fins to slightly anterior to the caudal peduncle were done. After that, the position of each section in terms of percentage body length (i.e. the tip the snout will be 0% the fork of the tail will be 100%) was calculated. Shape of the cross-sections including the shape and position of white and red muscle proportions was sketched. Transparent plastic sheet was placed over the cross-sections and an outline of white and red muscle was traced with fine, felt tipped pen. The tracing of white and red muscle (exclude vertebrae and body cavity sections) was cut out. Furthermore, the tracing and the cross-section was measured for the weight and the percentage of white and red muscle for each cross-section was calculated.

2.3 Buffering capacity of red and white muscle of marine fish

Red and white muscle from the mid-section was dissected out and any remaining skin or bone from the muscle sample was removed. After that, around 0.5 gram of red and white muscle each was placed to a vial and then 5 ml of 1.2% saline was added and homogenized. The pH meter was calibrated (pH 7) and the homogenized muscle sample was placed onto the pH meter. Then, initial pH of the sample was recorded and HCl was added to make the pH sample to 6. Twenty ul of NaOH was added to the sample and the change in pH was recorded. Furthermore, the measured drop was placed back into the vial before another 20ul of NaOH was added and pH changed was recorded until reach 7. Finally, the change in pH against the volume of base added was entered in Microsoft excel. To analyze the raw data plot the results as umol NaOH vs pH, linear regression model was made. After that, the buffering capacity (β) of each muscle type was calculated by working out the umoles of a base needed to change the pH by one pH unit per gram of tissue which called measured in slykes.

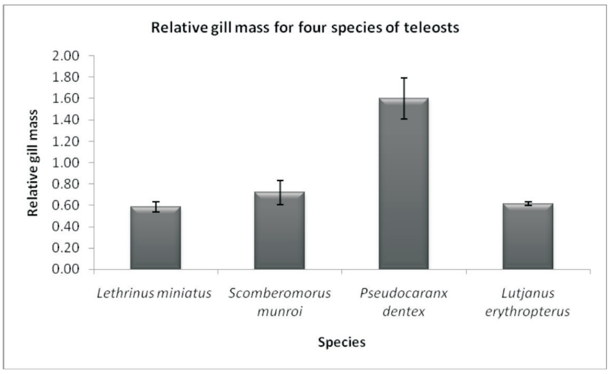
3 RESULTS

3.1 Scope for aerobic activity

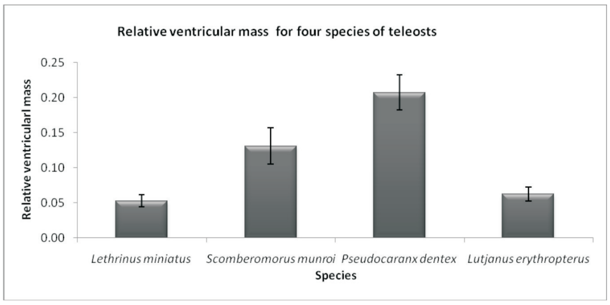
From the graph it can be seen that *Pseudocaranx dentex* have the higher both relative gill mass (figure 1) and ventricular mass (figure 2) compared to the three other species. The relative gill mass and ventricular mass of *Scomberomorus munroi* is the second largest which at 0.720 and 0.131 respectively, followed by *Lutjanus erythropterus* and *Lethrinus miniatus* (figure 1 and 2).

3.2 Proportion and location of red muscle

As can be seen from the graph (figure 3) that the proportion of red muscle from four species is increasing with the increasing of red muscle position along body which *Pseudocaranx dentex* have the higher proportion compared to others. While, the proportion of red muscle of *Lethrinus miniatus*, *Scomberomorus* munro and *Lutjanus erythropterus* along body is quite similar.



GAMBAR 1: Relative gill mass for four species of teleost

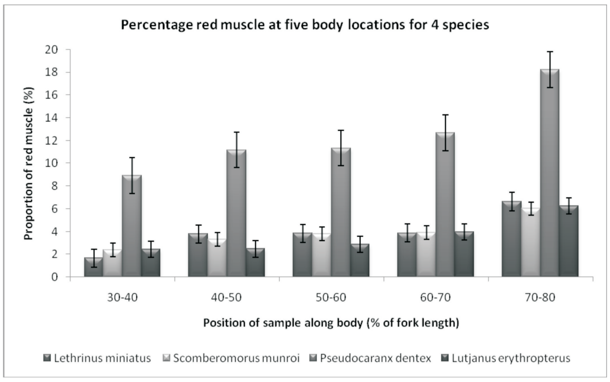


GAMBAR 2: Relative ventricular mass for four species of teleost

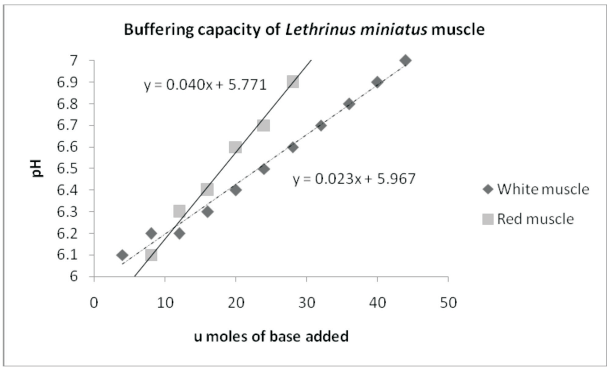
3.3 Buffering capacity of red and white muscle of marine fish

As clearly be seen from the graph (figure 4,5,6 and 7) that the buffering capacity of white muscle of four species is better than red muscle. The white muscle needs more u moles of base added to reach pH 7 than the red muscle. Furthermore, from linear regression model shows that *Pseudocaranx dentex* muscle have better ability for buffering capacity than three species which the equation for white muscle is y=0.023x+5.896 and red muscle is y=0.033x+5.914 (figure 5). While the buffering capacity of muscle from *Lethrinus miniatus* (white muscle y=0.023x+5.967 and red muscle y=0.04x+5.771), *Scomberomorus munro* (white muscle y=0.022x+6.228 and red muscle y=0.033x+6.189) and *Lutjanus erythropterus* (white muscle y=0.038x+6.025 and red muscle y=0.057x+6.18) is quite similar (figure 4, 6 and 7 respectively).

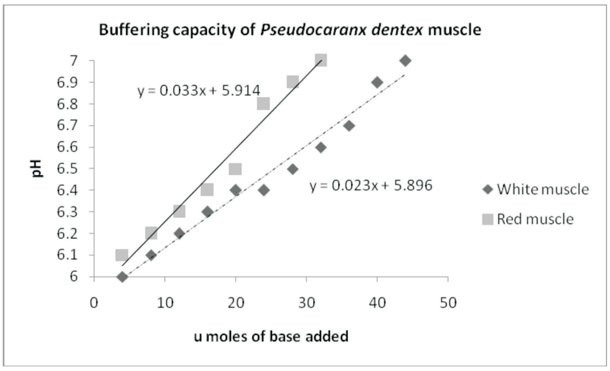
Moreover, the amount of base added to achieve a one step change in pH for a gram of red and white muscle tissue in *Pseudocaranx dentex*, *Lethrinus miniatus*, *Scomberomorus munroi*, *Lutjanus erythropterus* are 64 and 88, 56 and 88, 48 and 64, 32 and 56 respectively. Therefore, more bases added to white muscle to change in pH than red muscle.



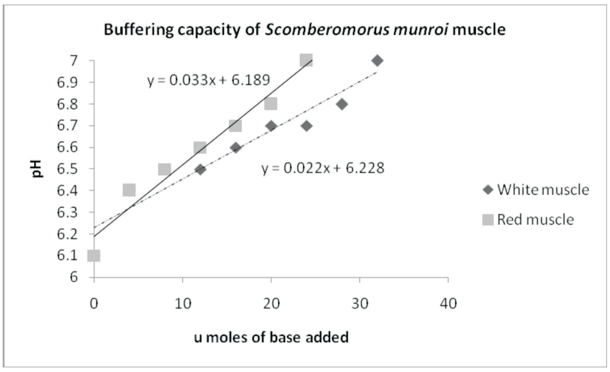
GAMBAR 3: Percentage of red muscle at five body locations for four species



GAMBAR 4: Buffering capacity of *Lethrinus miniatus* muscle



GAMBAR 5: Buffering capacity of *Pseudocaranx dentex* muscle



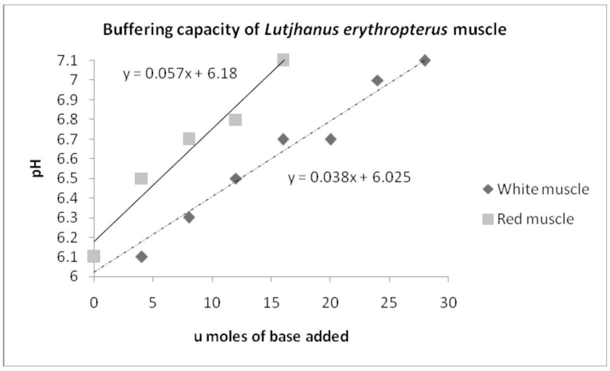
GAMBAR 6: Buffering capacity of *Scomberomorus munroi* muscle

4 DISCUSSIONS

The result shows that the relative gill and ventricular mass from four species provide relationship with their lifestyle and habitats. The relative gill and ventricular mass in Pseudocaranx dentex is the highest followed by *Scomberomorus munroi*. This species require higher aerobic activity because *Pseudocaranx dentex* is an active fish, which have depth range from 10 to 238m, and *Scomberomorus munroi* have depth range up to 100m[7]. The habitat of *Pseudocaranx dentex* and *Scomberomorus munroi* is in reef area and open water respectively and they always swims to allow seawater flows through their gills. To support their lifestly, their gills surface area and weight is bigger to provide efficiency in absorbance or difused the oxygen [2]. Also, the ventricular is bigger because the oxygen requirment for active fish is higher, so its have better ability to pump blood which carry oxygen to be distributed to organs[8,9]. Furthermore, oxygen can be used for important cellular metabolites to make energy for their activities. Higher relative ventricular mass and gill mass is found to correlate positively with maximum oxygen intake[10]. The way gills exchange gas is through the lamellae, arranged in rows along the paired gill arches located on either side of the pharynx, forming a sieve which water passes through. Blood flows in the opposite direction, creating a counter current system for gaseous exchange[11].

On the other hand, *Lethrinus miniatus* and *Lutjanus erythropterus* have similar relative gill and ventricular mass which indicate that they less active and lower oxygen requirement compared to *Pseudocaranx dentex* and *Scomberomorus munroi*. Therefore, active fish have the larger ventricle that will pump blood at a higher pressure to ensure that blood can reach all parts of the body[9]. Active fish also require more oxygen for their increased muscular mass and larger gill surface area is required to exchange more oxygen than the inactive fish[5].

The proportion of red muscle along the body seems to be similar for all species examined (Figure 3) except for *Pseudocaranx dentex* which have the highest proportion. The amount of each kind of muscle determines the type of swimming. Steady swimming involved exclusively red muscle activity while rapid unsteady swimming utilized red and white muscles [12]. Percentage of red muscle is also influenced by the lifestyle. More red muscle allows more aerobic scope for fast cruising and use up more oxygen[2]. Thus, they



GAMBAR 7: Buffering capacity of *Lutjhanus erythropterus* muscle

require a higher ventilation rate and efficient gills for oxygen intake. Active fish have higher proportion of red muscle than less active fish because they need a lot of oxygen to support their lifestyle[12]. Therefore, active fish tend to be aerobic stayer which supports their lifestyle to be active like always swims.

Position of muscles may also have an influence on timing of neural activation and shortening of muscle fibers which enhances the performance of the swimming type[13]. The slight increase of red muscle at the tail for four species is to generate thrust at the tail and produce substantial amount of power. All the red muscles in the body were simultaneously active for a locomotory cycle[12].

From buffering capacity of four marine fish muscle experiment show that white muscle took longer to reach pH 7. It indicate that the highest buffering capacities were found in white muscle which have capability of burst motion and low level anaerobic function. While, the red muscle have lower buffering capacity because they are involved in the aerobic energy pathway for slow swimming. Thus, muscle buffering capacity is strongly correlated with the ability of muscles to function anaerobically[14].

Furthermore, *Pseudocaranx dentex* and *Scomberomorus munroi* need higher base added than *Lethrinus miniatus* and *Lutjanus erythropterus* to achieve pH 7. Active fish which may always swim will needs a lot of oxygen to supply their energy requirement and if the oxygen storage is exhausted, anaerobic energy pathway will be needed. As a result, acid lactic will be produce if anaerobic glycolysis is conducted[14]. For active fish, they have better ability to handle acid in their muscle rather than inactive fish. In conclusion, it can be noticed that *Lethrinus miniatus* and *Lutjanus erythropterus* are less active than *Pseudocaranx dentex* and *Scomberomorus munroi*

DAFTAR PUSTAKA

[1] Mendes, B., Fonseca, P. and Campos, A., 2006, Relationships between opercula girth, maximum girth and total length of fish species caught in gillnet and trammel net selectivity surveys off the Portuguese coast, *J. Appl. Ichthyol.*, 22: 209-213

[2] Prosser, C.L. (Ed.), 1973, Prosser, C.L. (Ed.), 1973, *Comparative animal physiology*, W. B. Saunders Company, London., W. B. Saunders Company, London.

[3] Bruce, C.J., and George, V.L., 1995, Red muscle motor patterns during steady swimming in largemouth bass. Effects of speed and correlations with axial kinematics, *J. Exp. Biol.*, 198: 1575-1587

[4] Syme. D.A. and Shadwick, R.E., 2002, Effects of longitudinal body position and swimming speed on mechanical power of deep red muscle from skipjack tuna (*Katsuwonus pelamis*), *J. Exp. Biol.*, 205: 189-200

[5] Evans, D.H., Claiborne, J.B. (Eds.), 2006, *The physiology of fishes.* CRC Press, New York.

[6] Poupa, O., and Lindstrom, L., 1983, Comparative and scaling aspects of heart and body weights with reference to blood supply to cardiac fibres, *Comp. Biochem. Physiol.*, 76A: 413-421

[7] Froese, R., Pauly, D., 2009, FishBase, New York, Retrieved from http://www.fishbase.org/search.php, Viewed on 18 September 2009

[8] Santer, R. M., 1985, Morphology and innervation of the fish heart, *Adv. Anat. Embryology Cell Biol.*, 89:1-102

[9] Hoar, W.S., Randall, W.S and Farrell, A.P., 1992, *Fish physiology: the cardiovascular system, Vol. XII part A*, Academic press, New York, USA, 340pp.

[10] Odell, J.P., Chappell, M.A. and Dickson, K.A., 2003, Morphological and enzymatic correlates of aerobic and burst performance in different populations of Trinidadian guppies *Poecilia reticulate, J. Exp. Biol.*, 206: 3707-3718

[11] Piiper, J., 1989, Factors affecting gas transfer in respiratory organs of vertebrates, *Can. J. Zool.*, 67: 2956-2960

[12] Jayne, B. C. and Lauder, G. V, 1994, How swimming fish use slow and fast muscle fibers: implications for models of vertebrate muscle recruitment, *J. Comp. Physiol. and Sensory Neural & Behav. Physiol.*, 175: 123-131.

[13] D'aout, K., Curtin, N.A., Williams, T.L. and Aerts, P., 2001, Mechanical properties of red and white swimming muscles as a function of the position along the body of the eel *Anguilla anguilla, J. Exp. Biol.*, 204:2221-2230

[14] Castellini, M.A., Somero, G.N., 1981, Buffering capacity of vertebrate muscle: correlations with potentials for anaerobic function. *Journal of Comparative Physiology.* B, 143: 191-198.