OXYGEN CONSUMPTION OF SCALLOP *PECTEN MAXIMUS* IN DIFFERENT PHYSIOLOGICAL CONDITIONS

Djoko Suprapto

Faculty of Fisheries and Marine Science, Diponegoro University

ABSTRACT

The level of oxygen consumption is one of the indicators of organism physiological condition. It can be used to understand the energetical flow of the organism and finally some measures can be taken to manipulate the environmental condition in order to give the optimum environment to grow.

A semi open system or semi running system was used to measure the oxygen consumption. The principle of the measurement was to calculate the difference between the oxygen concentration of the water entering respiratory chambers with the one out of respiratory chambers.

This experiment was using Pecten maximus *coming from Brest, Scotland, Ireland, and Saint Brieux.*

Each population showing difference rate of oxygen consumption, meanwhile oxygen consumption influenced by bodyweight and other physiological conditions.

Scotland population having the best performance of energetical balance, compared with the other three populations.

I. INTRODUCTION

Much of the research on invertebrate especially on bivalve mollusc had been aimed at describing the physiological activity under a variety of conditions (Winter, 1973). This author stressed that an understanding of bioenergetic of bivalves requires knowledge of oxygen consumption and feeding activity. These parameters should be measured in such condition that

close to natural environment especially the partial pressure of oxygen of the water medium. Further more, it is important that the measurement apparatus can be modified to different physiological condition (Suprapto, 1986). By this type of equipment, a perfect acclimatization can be made before the measure started, a multiple measurement can be conducted, so that the value obtained will represent and reflect the metabolic activity of the animal, at least closed to the real value.

II. MATERIALS AND METHODS

2.1. Experimental Animals

Scallops were collected from the bay of Brest, by diving. They consist of three populations, different in their origins: (a) from the bay of Brest, (b) from Mulroy Bay (Ireland), (c) Skye Island (Scotland). Populations (b) and [c] were three years old so for the population from Brest, only three years old animals were used, and were of approximately similar size (B.: 9.70 - 13.56; Ir.: 8.59 - 12.05; S.: 8.95 - 12.80 cm) of length. They were cleaned carefully of any epibiotic growth and kept in aquaria equipped by gravel filter bed, in the Laboratory of Zoology, U.B.O, Brest. They allowed at least one week to aclimatize to the Laboratory conditions before being used for the experiments. During this acclimatization period, sea water was changed twice a week, and scallops were fed twice a day with the mixture of Dunaliella primolecta, Monochrisis lutheri, Tetraselmis suecica, and Phaeodactilum tricornutum, cultured in the laboratory.

The water temperature of the aquaria was 13^{0} C $\pm$ 1^{0} C and with the salinity of 33 - 35°/₀₀.

2.2. Experimental Conditions

All experiments were carried out in a system with the same salinity and temperature of recirculating sea water.

The room was cooled and the water was thermostated so that the temperature of water was constant during the experiments.

The system contained 120 liters of water which circulated from a reservoir tank equipped by a gravel filter bed to respiratory chambers via a column of 2 meters of height with an overflow on the top. The rate of water flow which passed through the respiratory chambers was controlled at 100 ml mn^{-1} (6 ℓ h^{-1}). The constancy of the debit was ensured by the hydrodynamic pression of water in the column. The water in the respiratory chambers was continuously agitated by means of magnetic stirers.

Due to the respiratory activity of the animals in the respiratory chambers, the oxygen tension of water that entered into the respiratory chambers will decline, and by this principle that the consumption of oxygen of the animals was computed.

2.3. Computation of Oxygen Consumption

Concentration of oxygen in the water can be calculated by the formula of Henry :

$$CO_2 = \alpha \, P \, O_2$$

where : α is the coefficient of solubility of oxygen in the water (refer to a table of Dejours, 1981), expressed in μ mol. l^{-1} torr^{-1}.
PO_2 is partiel pressure of oxygen in the water (torr).

Based on this formula, the oxygen consumption can be computed by the following equation:

$$MO_2 = \alpha \, (PO_2e - PO_2s) \, D$$

Where : PO_2e and PO_2s are the partiel pressure of oxygen of water that enter and pass the respiratory chambers. D is the debit of water that passed the respiratory chambers and expressed in l h^{-1}.

Thus oxygen consumption obtained will be in μ mol. h^{-1}, but in this work it was expressed in ml h^{-1}.

Each scallop was allowed at least one hour to equilibrate in the respiratory chamber, before the measurement was started. Oxygen consumption under two different physiological conditions was recorded: (a) Starved-scallops, not to be fed during 48 hours, (b) Fed-scallops, 40 ml of Dunaliella primolecta (2.5 10^{6} cells ml^{-1}) was injected into respiratory chambers every two hours, which give a concentration of 40.10^{6} cells l^{1}.

Each experiment was repeated ten times; thus, each average hourly rate of oxygen consumption, is actually based upon six hours forty minutes measurements.

After the experiments, the body of the scallops were removed and dried to a constant weight at 70^{0} C. The dry weight of tissue was used for calculating the relationship of oxygen consumption and body weight. This relationship was expressed in the form of an allometric equation, $MO_2 = a\ W^b$, where MO_2 is the oxygen consumption, W is the dry body weight, and a and b are the slope and the intercept of the log MO_2 vs. Log W regression, respectively.

III. RESULTS

The oxygen uptake and metabolic rate of scallops studied are presented in table 1.

Table 1. Oxygen uptake and metabolic rate of populations Brest (B.), Ireland (Ir.), and Scotland (S.) under starved and fed conditions.

Popu-lation	Range of dry body weight (g)	Range of oxygen uptake (ml h^{-1})		Range of metabolic rate (ml g^{-1} h^{-1})	
		starved	fed	starved	fed
B.	5.392 - 12.050	2.233 - 4.194	3.798 - 8.808	0.260 - 0.489	0.583 - 0.976
Ir.	4.098 - 14.135	2.654 - 5.393	4.055 - 11.519	0.362 - 0.739	0.797 - 1.508
S.	3.909 - 17.603	2.301 - 4.732	4.604 - 9.808	0.258 - 0.588	0.547 - 1.068

Oxygen consumption increased with increasing body weight, showing an exponential relationship. A positive linear relationship was obtained in all populations when log of oxygen uptake was plotted against log of dry body weight. Metabolic rate i.e., oxygen uptake per unit body weight per unit time, showed a decline with increasing body weight and showed a negative linear correlation when log of metabolic rate was plotted against log of dry body weight. The relationship between oxygen uptake and dry body weight of all populations are expressed in an allometric equation and the appropriate statistical data are presented in table 2.

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Table 2. Statistical information for data of allometric equation relating oxygen uptake (MO₂) and dry body weight (W). r is the coefficient correlation, N is number of animals studied, and S.E standard error of b.

Pop.	Condition	$MO_2 = a W^b$	r	N	S.E of (b)
B	starved	$0.703\ W^{0.704}$	0.889	32	0.066
B	fed	$0.759\ W^{0.978}$	0.845	32	0.112
Ir	starved	$1.343\ W^{0.475}$	0.957	33	0.025
Ir	fed	$1.572\ W^{0.770}$	0.951	33	0.044
S	starved	$0.870\ W^{0.583}$	0.970	30	0.027
S	fed	$2.118\ W^{0.533}$	0.953	30	0.032

The oxygen consumption in starved-scallops corresponds to the energetic cost of standard metabolism. The increase of oxygen consumption in animals from all populations measured in fed-scallops is principally due to the filter feeding activity (mechanical cost) of these scallops.

The increase of a value shows a variation from one population to another. It was probable that response to feeding of animals was different in one population with another. Population from Scotland showed a higher increase than the other two populations.

The weight exponent (b value) varies also from one population to another and it differs according to the physiological condition where the fed-scallops have a higher weight exponent than the straved one.

Brest population: The weight exponent for starved-scallops metabolic rate was 0.704, shows a departure from 'two thirds power' of body weight. While for fed-scallops the b value was 0.978 i.e., approximated to weight proportional metabolism.

Ireland population: the b value for starved-scallops metabolic rate was 0.475, that means neither surface nor weight proportional metabolism. For the fed-scallops, the weight exponent was 0.770, i.e., intermediate between surface proportional and weight proportional metabolism.

Scotland population: both b values (starved and fed-scallops), 0.583 and 0.533 approximated to surface proportional metabolism. The reason for this difference in weight exponent is not clear. In a discussion of this problem Bertalanffy (1964) in Thomson and Bayne (1972) points out that in some cases the weight exponent is greater for fed than for starved animals.

In these experiments where the principal interest was to compare the metabolic rate between these populations (B., Ir., and S.), so the comparisons between b and a values of the three populations which include in the comparison of regression lines will be discussed. The regression lines were compared and tested by analysis of covariance (Snedecor and Cobran, 1967).

The analysis of variance for different regressions relating oxygen consumption on dry body weight showed the following results :

a. Starved-scallops: all regressions differ from each other, that means the metabolic rate of one population was different with the others.

b. Fed-scallops : regression lines of Brest population and that of Scotland can be compared since their residual variances were not homogeneous. However comparison of Brest-Ireland and Ireland-Scotland showed significantly different.

During feeding, the metabolism of previously starved-scallops is raised above the non-feeding, to a level which we terme 'active metabolism'. The difference between the active and the standard rate is defined as the 'scope for activity' (Fry, 1971) which is a measure of the metabolic cost of activity of the organism. In this study the cost of activity was the difference between oxygen consumption of fed-scallops with that of starved-ones.

The results showed that population from Ireland has the highest value of scope for activity (2.475 cal), followed by Scotland population and Brest population.

IV. DISCUSSIONS

The relationship between oxygen consumption and dry body weight showed that the oxygen uptake vary with weight. The energy expenditure increase with the size of organism but not in direct proportion, that means ametabolic rate or weight specific oxygen consumption is more for smaller animals and less for the larger ones. The weight exponent, 'b' values obtained in this study showed a variation according to the population and the physiological conditions.

Amongst bivalves there are not only interspecific differences in the value of 'b', but studies in the same species by different workers have produced varied values for this exponent.

The variations of 'b' values are perhaps attributable to the fact that different populations were studied (Taylor and Brand, 1975). The 'b' values, depends, among other factors, on the relative effects of activity, temperature and salinity, on the oxygen consumption of large and small individuals (Newell, 1979). So that any factor which has interaction with body size will be expressed in a variation of the value of the slope of regression relating metabolism to body size. The 'b' values may vary with rations (Widdows, 1978), starvation (Newell, Roy, and Armitage, 1976), and aquatic conditions (Toulmon, 1967).

The slopes of regression relating fed-scallops oxygen consumption and dry body weight showed higher values than the starved ones (for the populations of B. and Ir.), signifying that the larger animals exhibited higher rate of oxygen consumption than smaller ones. This phenomenon was not for the population 'S.' where this population showed very high in the intensity of metabolic during feeding, but such increase in larger animals was inferior to the small ones.

The nature of increase of metabolic rate in fed-scallops was probable due to the increased of mechanical cost of ventilation rate and physiological cost of feeding. In this present study, the

variation of 'b' values was from 0.475 to 0.978, these values were in agreement with that given by Bayne et al. (1976) where it was pointed out that 'b' values range from 0.16 to 1.02 and most of them fall within the range of 0.4 to 0.9.

The activity of feding of the scallops in this experiments, not only affect the slopes, but also the elevations to a greater value in the regression lines. The increase of elevation signifying that during feeding activity, the intensity of metabolic of fed-scallops was greater than the starved ones. Such differences, both in slopes and elevations between feeding and non feeding oxygen uptake were noticed by Thompson and Bayne (1972) in Mytilus edulis.

Each population has difference response to feeding and has resulted a variation in the value of scope for activity, this value can provide an index not only of the energy available for activity (both mechanical and physiological) but of the possible conservation by reducing the activity and minimize the oxygen uptake.

The difference in the value of scope for activity will be more valuable if a study about effectiveness of energy expenditure which we terme energetic balance and growth rate can be conducted.

REFERENCES

Bayne B.L.., Bayne C.L., Carefoot T.C., et Thompson R.J., 1976. The Physiological Ecology of Mytilus Californianus Conrad (I) Aspects of Metabolisme and Energy Balance. Oecologia (Berl), 22: 211-228.

Fry F.E.J., 1971. The Effect of Environmental Factors on the Physiology of Fish. In Fish Physiology, Ed. Hoar W.S. and Randall D.J., 6: 1-98.

Newell, R.C. 1979. Biology of Intertidal Animals. Marine Ecological Surveys Ltd.Faversham, Kent. 781p.

Newell, R.C., Roy A. et Armitage K.B., 1976. An Analysis of Factors Affecting the Oxygen Consumption of the Isopod Ligia Oceanica. Physiol. Zool., 49 (1): 109-137.

Snedecor G.W. & Cohran W.G., 1967. Statistical Methods. Iowa State University Press, Iowa. 6th Edition. 593 p.

Suprapto, Djoko. 1986. Ecophysiologie de Differentes Populations Genetiques de Pecten maximus L. These de 3e Cycle, L'Universite de Bretagne Occidentale, Brest.

Taylor A.C. et Brand A.R. 1975a. Effects of Hypoxia and Body Size on the Oxygen Consumption of the Bivalve Arctica islandica (L). J. Exp. Mar. Biol. Ecol., 19 : 187 - 196.

Taylor, A.C., and Brand A.R., 1975b. A Comparative Study of the Respiratory Responses of the Bivalves Arctica islandica (L.) and Mytilus edulis (to Declining Oxygen Tension). Proc. Roy. S.O.C. (Lond.), B., 190: 443-456.

Thomson R.J. et Bayne B.L., 1972. Active Metabolism Associated with Feeding in the Mussel Mytilus edulis L. J. Exp. Mar. Biol. Ecol., 8 : 191 - 212.

Toulmond, A., 1967. Etude de la Consommation d'Oxygen en Fonction du poid dans l'air et dans l'ean, Chez Quatre Especes du Genre (Gastropoda, Protobranchiata). C.R. Acad. Sci. Paris, 264: 636-638.

Widdows J. 1978. Combined Effects of Body Size, Food Concentration and Season on the Physiology of Mytilus edulis. J. Mar. Biol. Ass. U.K., 58 : 109 - 124.

Winter J.E. 1973. The Filtration Rate of Mytilus edulis and its Dependence on Algal Concentration, Measured by a Continuous Automatic Recording Apparatus. Mar. Biol., 22 : 317 - 328.