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Metabolic rates in excised tissues of carp

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Summary. Oxygen consumption in vitro of carp tissues ranged from 7.60 $\mu l \cdot min^{-1} \cdot g^{-1}$ for brain to undetectable for fat in the following order: brain, kidney, intestine, dark muscle, hepatopancreas, ventricle, gill filaments, testis, ovary, erythrocytes, vertebrae, ordinary muscle, blood, and fat. Summated oxygen consumption in vitro of the tissues approximately coincided with oxygen consumption in vivo of intact animal.

Oxygen consumption in vitro (Q_{O_2}) of tissue is a basic parameter of metabolic activity of the tissue. The values of Q_{O_2} have been determined in several fishes, but they were limited to only a few tissues for any single species. Brain, liver and muscle from menhaden, toadfish and scup[1]; brain, liver and gills from goldfish[2]; kidney and gills from cutthroat trout[3]; muscles from 2 tunas[4]; gills from 2 sunfishes[5]; rectal gland, spleen and kidney from dogfish[6]; and gills from Atlantic cod[7] have been examined. This paper presents data on Q_{O_2} for 14 tissues covering most of the main organs of carp. The relationship between these figures and the oxygen consumption of the intact animals is discussed.

Material and methods. The experiments were carried out on 88 carps *Cyprinus carpio* of 213 ± 82 g ($\bar{X} \pm SD$) kept for 2 weeks or more. They were fed with pellets made from fish meal (38%), wheat flour (29%), soybean cake (15%), vitamins and minerals, except 1 or 2 days before experimentation. A fish was instantly killed by a spinal abscission and the tissues immediately excised. Excised tissues were prepared for Q_{O_2} determination by the following methods, which have been found to give the most reliable results for various tissues (Oikawa and Itazawa, in preparation). Most of the tissues were prepared by chopping with scissors about 400 times, until the tissue became pasty, in a chilled weighing bottle. Gill filaments, erythrocytes, blood and fat were examined with intact tissue, and vertebral centra were prepared by grinding them by a file. Oxygen consumption of the tissue preparation was determined by Warburg's manometric method at 20 °C using Cortland saline[8] containing 5.6 mM glucose as the substrate solution. A substrate solution containing Na-pyruvate, Na-fumarate and Na-L-glutamate besides glucose gave almost the same results for various tissues as the solution containing glucose only (Oikawa and Itazawa, in preparation).

Results and discussion. The highest value of Q_{O_2} was obtained with the brain which showed 7.60 $\mu l \cdot min^{-1} \cdot g$ (wet wt)$^{-1}$, while the lowest one was with fat, for which the value did not differ significantly from zero. The 14 tissues examined were arranged in the following order mainly based on statistically significant differences ($p < 0.05$): brain, kidney > intestine > dark muscle, hepatopancreas > ventricle, gill filaments > testis > ovary, erythrocytes, vertebral centra, ordinary muscle > blood > fat (table 1). Summation of tissue respiration in vitro was attempted to compare with the respiration in vivo of the intact animal using the same individuals. Oxygen consumption in vivo of a carp of 110–140 g was determined by a constant flow method at 20 °C making 6 measurements each time. The oxygen consumption was 1.67 ± 0.10 $\mu l \cdot min^{-1} \cdot g$ (wet wt)$^{-1}$ ($\bar{X} \pm SD$). After the experiments, the fish were sacrificed to weigh the various tissues composing the body. Oxygen consumption in vitro of a whole animal was estimated by dividing the summated oxygen consumption of various tissues by the summated weight of the tissues.

Table 1. Oxygen consumption in vitro of carp tissues

Tissue	Preparation	Q_{O_2} ($\mu l \cdot min^{-1} \cdot g^{-1}$) N (fish)	$\bar{X}$	SD
Brain	Chopped[c]	10	7.60	±0.83
Kidney	Chopped	10	6.91	±1.15
Intestine	Chopped	10	5.35	±0.92
Dark muscle[a]	Chopped	10	4.26	±0.95
Hepatopancreas	Chopped	11	4.22	±1.03
Ventricle	Chopped	10	3.33	±0.80
Gill filaments	Intact	13	3.10	±0.72
Testis	Chopped	10	2.46	±0.57
Ovary	Chopped	10	1.87	±0.51
Erythrocytes	Intact	8	1.53	±0.71
Vertebral centra	Ground	7	1.08	±0.40
Ordinary muscle	Chopped	10	1.04	±0.52
Blood	Intact	8	0.42	±0.13
Fat[b]	Intact	8	0.25	±0.65

[a] Reddish muscle of the lateral regions of the body. [b] Fat collected from the intracranial region. [c] Chopping was carried out with scissors.

Table 2. Summated oxygen consumption in vitro of carp tissues

Tissue[a]	Q_{O2} ($\mu l \cdot min^{-1} \cdot g^{-1}$)	Body weight 114 g Weight[a] (g)	O_2 cons.[b] ($\mu l \cdot min^{-1}$)	136 g Weight[a] (g)	O_2 cons.[b] ($\mu l \cdot min^{-1}$)	138 g Weight[a] (g)	O_2 cons.[b] ($\mu l \cdot min^{-1}$)
Trunk[c]	1.10[d]	59.173	65.09	69.680	76.65	72.029	79.23
Head[e]	1.83[f]	27.765	50.81	38.385	70.24	36.961	67.64
Intestine	5.35	2.654	14.20	2.824	15.11	2.501	13.38
Hepatopancreas	4.22	2.358	9.95	3.030	12.79	2.615	11.04
Gonads	2.17[g]	1.750	3.80	2.000	4.34	0.843	1.83
Gill filaments	3.10	1.624	5.03	1.880	5.83	2.096	6.50
Kidney	6.91	0.735	5.08	0.701	4.84	0.723	5.00
Brain	7.60	0.396	3.01	0.405	3.08	0.443	3.37
Ventricle	3.33	0.088	0.29	0.150	0.50	0.133	0.44
Summation		96.543	157.26	119.055	193.38	118.344	188.43
Estimated total O_2 consumption[h] ($\mu l \cdot min^{-1} \cdot g^{-1}$)		1.63		1.62		1.59	

[a] Organ of region. [b] Q_{O_2} of a tissue multiplied by the tissue weight. [c] Trunk region except fins and viscera. [d] Total Q_{O_2} of trunk calculated from Q_{O_2} ($\mu l \cdot min^{-1} \cdot g^{-1}$) and weight proportion (%) of 5 main components, ordinary muscle (1.04, 81.09), skin (1.3, 7.03), scales (0.70, 6.86), bones (1.08, 3.20), and dark muscle (4.26, 1.82). [e] Head region except brain, gill filaments and heart. [f] Q_{O2} of head in small carp of about 2 g. [g] Mean value of Q_{O_2} of testis and ovary. [h] Summated O_2 consumption divided by summated weight.

The estimated oxygen consumption in vitro, 1.63, 1.62 and 1.59, gave the mean value of 1.61 $\mu l \cdot min^{-1} \cdot g$ (wet wt)$^{-1}$ which approximately coincided with oxygen consumption in vivo of the intact animal, 1.67, although 14% of the body were counted out and functional activity of organs was neglected in the former (table 2).
The decline in weight-specific rate of basal metabolism of an intact animal with increasing body size could be explained, partly at least, if tissues with low metabolic rates get larger with growth in weight in proportion to the whole body. This hypothesis is now being examined, based on the present results and figures for the relative growth of tissues and organs.

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Effect of starvation on enzymes related to lipid metabolism in guinea-pig lungs

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Summary. The changes in activities of acetyl CoA carboxylase, microsomal fatty acid elongation enzyme, choline phosphotransferase, triglyceride lipase, phospholipase A_1 and phospholipase A_2 were followed in guinea-pig lungs at 24, 48 and 72 h after food deprivation. Triglyceride lipase was elevated and phospholipase A_1 and phospholipase A_2 were unaffected, while the other activities decreased. The significance of these findings in relation to food deprivation is discussed.

There is evidence suggesting that an increase or decrease in lipid intake affects the lung lipid content and the activity of lung lining material[2,3]. Faridy[4] has shown that food deprivation resulted in an increased tendency of the lungs to collapse, associated with a lowered content of phosphatidylcholine, the major surface active lipid. Scholtz and Rhodes[5] found a 40% decrease in lung lipid synthesis from glucose in fasted rats. Gross and co-workers[6] have reported changes in various phospholipids in developing lung due to nutritional deprivation. Gross et al.[7] also reported changes in a few enzymes of lipid metabolism after 4 days of fasting in albino rats. However, a systematic and detailed study of the effect of starvation on enzymes related to lung lipid metabolism has not been reported[8]. Therefore, changes in acetyl CoA carboxylase, microsomal fatty acid elongation enzyme, choline phosphotransferase, triglyceride lipase, phospholipase A_1 and phospholipase A_2 have been studied in guinea-pig lungs after 24, 48 and 72 h of fasting. The findings are reported below. We chose to use guinea-pigs, because they do not synthesize ascorbic acid as rats do.

Materials and methods. 24 male guinea-pigs weighing 300–350 g (14 weeks old) from the Small Laboratory Animal Division, Indian Veterinary Research Institute, Izatnager were selected for study. 12 guinea-pigs were kept fasting. Remaining 12 guinea-pigs were provided with food ad libitum. After 24, 48 and 72 h of fasting, 4 animals from each group were sacrificed by exsanguination, and their lungs taken out, washed well in normal saline and immediately chilled in 0.01 M Tris Hcl pH 7.4 containing 0.001 M EDTA and 0.25 M sucrose. The lungs were then homogenized, filtered through muslin and fractionated by differential centrifugation as described by Gross and War-