Effects of Meal Size on the SDA of the Taimen

Guiqiang Yang a,*, Ding Yuanb,*, Wentong Li, Liying Zhang and Meng Zhao

Beijing Fisheries Research Institute, National engineering technology research center for freshwater fisheries, Beijing 100068.
Email: aygqbj2013@163.com; b512225638@qq.com

Abstract. Specific dynamic action (SDA), the metabolic phenomenon resulting from the digestion and assimilation of a meal, is generally influenced by body mass. The effects of ration level on SDA of taimen (Hucho taimen, Pallas) was evaluated, by measuring the temporal pattern of the oxygen consumption rates of taimen with meal size, 1/3 satiation, 2/3 satiation and satiation, after feeding, at 17.5°C. °C With the approximate body mass but different meal size, both Peak VO2 and SDA had a tendency to increase with increased meal size. Factorial scope of peak Vo2 and Duration had a tendency to increase with increased meal size.

1. Introduction
Feeding causes an increase of metabolic rate, which initially escalates rapidly, reaches a peak value and then gradually declines to the pre-feeding rate. This phenomenon, termed “specific dynamic action”(SDA) [1,2], reflects the energy requirements of the behavioral, physiological and biochemical processes that constitute feeding, including capture, handling, ingestion, digestion, the assimilation of prey and the increased synthesis of proteins and lipids associated with growth[3-5].

The parameters that are usually used to describe SDA include SMR (Standard metabolic rate), peak Vo2, factorial scope of peak Vo2, Duration, SDAE (energy expended on SDA, kJ• kg−1) and SDA coefficient [3, 6]. These parameters of the SDA depend on the species [6, 7], meal size [7, 8], meal type [6, 8, 9], feeding frequency [10], temperature [11] body mass [12], and composition of the diet [13].

Results from earlier studies suggest that SDA is dependent on meal size in some ectotherms [6]. However, only a limited number of studies have evaluated on the effects of body mass on SDA were related to fish[7, 8, 14]. No previous study, as far as is known, has reported the influence of body mass on SDA response in taimen.

Taimen are the largest specie in the Salmonidae family and the distribution of taimen has been seriously diminished by dams, water diversion, pollution and overfishing [15]. As a result of its decline, the taimen is now listed as a threatened species throughout its native range, and is being considered for listing in the International Union for Conservation of Nature’s (IUCN) red list [16]. The relationship of the metabolic rates of this unfed fish with body mass have been studied by Kuang [17]. But no studies have explored the effects of meal size on the SDA responses of taimen. There were two major objectives of the present study: 1) to determine whether this taimen responds to increasing meal size by increasing peak Vo2 and SDA; 2) to document Duration and SDA coefficient of this taimen.

2. Materials and Methods
Taimens were obtained from Yudushan Coldwater Fishery Base of Beijing Fisheries Research Institute and acclimated to the diets (Oryzias latipes, body mass 0.45-0.55g) in a rearing system for 2 weeks prior to the metabolism experiment. During this period, the fish were fed with their diet twice per day
(at 10:00, 16:00). The ingredients of the experimental diets are listed in Table 1. The oxygen content was kept above 5 mg • L⁻¹, the pH ranged from 7.3 to 8.0 and ammonia-N was kept below 0.025 mg • L⁻¹ during the experimental period. A 12/12-h (light/dark) photoperiod was used to simulate natural light cycle.

Table 1. Effects of meal size on several variables of SDA in taimen

| Variables                          | 1              | 2              | 3              |
|-----------------------------------|----------------|----------------|----------------|
| Meal size (% of body mass)        | 2.15±0.15      | 3.95±0.21      | 6.36±0.23      |
| Body mass (g)                     | 29.75±1.18     | 27.00±0.95     | 27.25±1.23     |
| SMR (mg•kg⁻¹•h⁻¹)                 | 144.58±4.37    | 148.89±2.36    | 146.92±5.12    |
| Peak VO₂ (L/min)                  | 175.81±2.89    | 186.67±5.84    | 218.42±6.03    |
| Factorial scope of peak VO₂       | 1.22±0.06      | 1.25±0.06      | 1.49±0.10      |
| Duration (h)                      | 14.67±0.41     | 16.00±0.28     | 17.33±0.35     |
| SDA (kJ/kg)                       | 3.72±0.05      | 4.37±0.05      | 9.11±0.08      |
| SDA coefficient (%)               | 31.55±1.24     | 22.23±0.98     | 28.51±1.36     |

Experimental protocol: The SDA response was measured with meal size (1/3 satiation, 2/3 satiation and satiation) using fifteen fish (five fish per group, three repeated groups in each ration level). Five fish were acclimatized in perforated plastic cages with a surface area of 1500 cm² and a water volume of 60 L. Each cage was put in a recirculating system, and the temperature was controlled at 17.5±0.5°C. Then the fish were acclimated for 2 weeks prior to the experiment. The oxygen consumption rate (OR) was measured continually during this period for three repeated groups per temperature level. After 24 h fast, the fish were placed in the chamber and allowed to acclimate for 24 h without food. OR was measured one time at 1 h intervals and used as standard metabolic rate. Then the different ration level (1/3 satiation, 2/3 satiation and satiation) of experiment diet was offered to the experimental fish. After the fish finished the diet, the chambers were closed immediately, and the OR was monitored. The duration was determined by a pilot experiment and guaranteed the postprandial metabolic rate returning to the prior status. Energy content of the diets (Oryzias latipes) was determined by bomb calorimetry (CN61M/1B, Beijing zhongxi tiaan Co., Ltd. China). Dissolved oxygen concentration was measured at the outlet of the chamber by an oxymeter (YSI 550A, YSI Incorporated, USA).

For each metabolic trial, several variables were quantified, as described by Jobling [3] and Stephen [6]: (1) standard metabolic rate (SMR); (2) peak VO₂; (3) factorial scope of peak VO₂; (4) duration; (5) SDAₑ, and (6) SDA coefficient (%). The oxygen consumption was converted to energy using a conversion factor of 13.56 J mg O₂–¹ [18]. A monofactorial variance analysis was performed using SPSS16.0 to compare the variables among different levels. P < 0.05 was considered significant. All data are presented as means ± S.E. Non-linear estimation was also used when necessary. Figures were drawn by Microsoft Excel software.

3. Results
There was no significant difference in body mass (n=15, P=0.394) among different meal size groups (Table 1). With each ration level, metabolic rate increased significantly 1 h after feeding, peaked at 6 to 7 h post-feeding, and then decreased gradually to the fasting level (Fig. 1). With the approximate body mass but different meal size, both Peak VO₂ and SDA had a tendency to increase with increased meal size (SMR, n=15, P<0.001; Peak VO₂, n=15, P<0.001) (Table 1). The relationship between Peak VO₂ (mg•kg⁻¹•h⁻¹) and meal size (m, %) was described as: Peak VO₂ = 155.17e^0.0523m, (R² = 0.9716, n=15, P < 0.001). The relationship between SDA ((kJ/kg)) and meal size (m, %) was described as: SDA = 2.1412e^0.2178m, (R² = 0.9285, n=15, P < 0.001).
Figure 1. The metabolic rate (mg•kg⁻¹•h⁻¹) in taimen with different body masses (●: meal size 2.15%; ▲: meal size 3.95%; ■: meal size 6.36%; □: unfed).

Just the contrary, factorial scope of peak \( V_o^2 \) and Duration had a tendency to increase with increased meal size (Table 1). The relationship between factorial scope of peak \( V_o^2 \) and meal size (m, %) was described as: factorial scope of peak \( V_o^2 = 1.0731e^{0.0489m} \), \( (R^2 = 0.8959, n=15, P=0.047) \). The relationship between Duration (h) and meal size (m, %) was described as: Duration = 0.6274m + 13.394, \( (R^2 = 0.9931, n=15, P < 0.001) \).

4. Discussion

Similar to most published studies, SDA duration increased with increased meal size [19, 20]. But SDA duration exhibited a slow–fast increase course with a gradual increase of meal size (Table 1). It is interesting that in relationship: Duration = a + b m, when meal size (m) goes to zero, the duration goes to a, which could be considered as minimum duration of SDA in the Hucho taimen. In this study the value of “a” was 13.39, which was a little lesser than the duration of 2.15% body mass group (14.67). So the minimum duration of SDA in the Hucho taimen was about 14 h.

The relationship between meal size and peak \( V_o^2 \) was complicated. The research on polar animals such as Antarctic plunderfish (\textit{Harpagifer antarcticus}) and limpet (\textit{Nacella concinna}) showed that the peak \( V_o^2 \) was not significantly increased with increased meal size because of the narrow metabolic scope, and they primarily relied on extending the digestive course to meet the energy requirement [21, 22]. Some studies in fishes and other animals found peak \( V_o^2 \) increased curvilinear with meal size [19, 23]. In this study, peak \( V_o^2 \) increased with meal size as meal size increased from 2.15 to 6.36% body mass.

Factorial scope of peak \( V_o^2 \) of this Hucho taimen was 1.22–1.49. The value was much lesser than those of all other documented work on any fish species [21, 24, 25], which usually ranged from 1.5 to 2.5.

5. References

[1] Xie, X.J., Sun, R.Y.: Advances of the studies on the specific dynamic action in fish. Acta. Hydrobiologica Sinica 15, 82-90 (1991)
[2] McCue, M.D.: Specific dynamic action: a century of investigation. Com. Bio. Phy. A. 144, 381-394 (2006)
[3] Jobling, M.: The influences of feeding on the metabolic rate of fishes: a short review. Journal of the Fish Biology 18, 385-400 (1981)
[4] Jobling, M.: Bioenergetics: feed intake and energy partitioning. In: Rankin, J.C., Jensen, F.B., (eds) Fish ecophysiology. Chapman & Hall, London (1993)
[5] Wells, M.J., Odor, R.K., Mangold, K., Wells, J.: Feeding and metabolic rate in \textit{Octopus}. Marine
and Freshwater Behaviour and Physiology 9, 305-317 (1983)

[6] Stephen, M.S., Jessica, A.W.: Effects of meal size, meal type, and body temperature on the specific dynamic action of anurans. J. Comp. Physiol. B 177, 165-182 (2007)

[7] Jobling, M., Davis, P.S.: Effects of feeding on metabolic rate, and the specific dynamic action in place. Journal of the Fish Biology 16, 629-631 (1980)

[8] Secor, S.M., Faulkner, A.C.: Effects of meal size, meal type, body temperature and body size on the specific dynamic action of the marine toad, Bufo marinus. Physiological and Biochemical Zoology 75, 557-571 (2002)

[9] Pan, Z.C., Xiang, J., Lu, H.L., Ma, X. M.: Influence of food type on specific dynamic action of the Chinese skink Eumeces chinensis. Comparative biochemistry and physiology Part A 140,151-155 (2005)

[10] Guinea, J., Fernandez, F.: Effect of feeding frequency, feeding level and temperature on energy metabolism in Sparus aurata. Aquaculture 148,125-142 (1997)

[11] Robertson, R. F., Meagor, J., Taylor, E.W.: Specific dynamic action in the shore crab, Carcinus maenas L., in relation to acclimation temperature and to the onset of the emersion response. Phy. Bio. Zool. 75, 350-359 (2002)

[12] Beaufre, S.J.: Technical Comment: Ratio representations of specific dynamic action (mass-specific SDA and SDA coefficient) do not standardize for body mass and meal size. Physiological and Biochemical Zoology 78, 126-131 (2005)

[13] Peter, T.: Relationship between specific dynamic action and protein deposition in calanoid copepods. J. Exp. Mar. Biol. Eco. (2000)

[14] Brodeur, J.C., Calvo, J., Johnston, I. A.: Proliferation of myogenic progenitor cells following feeding in the sub-antarctic notothenioid fish Harpagifer bispinis. J. Exp. Biol. 206, 163-169 (2003)

[15] Holcik, J., Hensel, K., Nieslanik, J.: The Eurasian Huchen Hucho hucho: Largest Salmon of the World, Kluwer Academic Publishers, Hingham USA (1988)

[16] Matveyev, A.N., Pronin, N.M., Samusenok, V.P., Bronte, C.R.: Ecology of Siberian taimen Hucho taimen in the Lake Baikal Basin. Journal of Great Lakes Research 24, 905-916 (1998)

[17] Kuang, Y.Y., Yin, J.S., Jiang, Z.F., Xun, W., Li, Y.F.: The correlation between oxygen consumption of Hucho taimen and body weight, water temperature. Chinese Journal of Fisheries 16, 23-30 (2003)

[18] Elliott, J.M., Davison, W.: Energy equivalents of oxygen consumption in animal energetics. Oecologia 19,195-201 (1975)

[19] Toledo, L.F., Abe, A.S., Andrade, D.V.: Temperature and relative meal size effects on the postprandial metabolism and energetics in a boid snake. Physiol Biochem Zool 76, 240-246 (2003)

[20] Fu, S.J., Cao, Z.D., Peng, J.L.: Effect of meal size on postprandial metabolic response in Chinese catfish (Silurus asotus Linnaeus). Comparative biochemistry and physiology Part B 176, 489-495 (2006)

[21] Boyce, S.J., Clarke, A.: Effect of body size and ration on specific dynamic action in the Antarctic plunderfish, Harpagifer antarcticus Nybelin. Physiol Zool 70, 679-690 (1997)

[22] Peck, L.S., Veal, R.: Feeding, metabolism and growth in the Antarctic limpet, Nacella concinna. Mar. Biol. 138, 553-560 (2001)

[23] Fu, S.J., Xie, X.J., Cao, Z.D.: Effect of meal size on postprandial metabolic response in southern catfish (Silurus meridionalis). Comp. Biochem Physiol A 140, 445-451 (2005)

[24] Hunt von Herbing, I., White, L.: The effects of body mass and feeding on metabolic rate in small juvenile Atlantic cod. J. Fish. Biol. 61, 945-958 (2002)

[25] Peck, M.A., Buckley, L.J., Bengtson, D.A.: Energy losses due to routine and feeding metabolism in young-of-year juvenile Atlantic cod (Gadus morhua). Can. J. Fish. Aquat. Sci. 60, 929-937 (2003)