Effects of different three live foods on growth performance and survival rates in Beluga *(Huso huso)* larvae

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Abstract

To determine the best live food and to reevaluate the optimal weaning period for beluga fish *(Huso huso)* larvae, seven experimental diets: Daphina (DP), Chironomids (CH), Gammarid (G), Daphina + formulated diet (DPFD), Chironomids + formulated diet (CHFD), Gammarid + formulated diet (GFD) and formulated diet (FD) in triplicate groups were fed to 4662 sixteen-days-old larvae which were captured from the stock tank and randomly distributed into 21 tanks. The microdiets contained 48-50% crude protein, 12-13% crude fat, 9-11% moisture and 8.5-9.5% ash. After 25 days feeding trial, weight gain (WG), specific growth rate (SGR) and feed efficiency (FE) of fish fed CHFD were significantly higher than those of fish fed the other diets ($P<0.05$). Frequent cannibalism and higher mortality in larvae fed G, GFD and FD diets were observed. These results may show the importance of live food followed by formulated diets in a gradual application pattern, as early as on the fourth to fifth day after hatching.

Keywords: Beluga larvae, *Huso huso*, Live food, Specific growth rate, Survival

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Introduction

Production of juvenile marine fish in commercial hatcheries still depends on live prey, such as rotifers and *Artemia.* Substitution of compound diets for live prey is crucial for lowering production cost and for sustaining production of high and constant quality juveniles (Bai et al., 2001). Until now, substitution of compound diet for live prey, known as weaning, is only performed some weeks after hatching in marine fish, while freshwater species can be fed compound diets as early as at mouth opening (Chau and Zambonini Infant, 2001).

Beluga aquaculture is a relatively new industry in many countries such as Iran and Korea; hence, information on nutrient utilization and dietary requirements in this fish is limited (Mohseni et al. 2006a; Mohseni, 2008). The culture of Beluga *(Huso huso)* larvae has usually relied on cultured or wild live food. This can be expensive in the case of culturing live food and unreliable in the case of harvesting wild live food. Rearing of sturgeon larvae has received increasing attention in recent years (Buddington and Doroshov, 1984), due mostly to the fact that in several countries the wild stock of these migratory fish is severely depleted or in danger of disappearance. The development of hatchery technology for sturgeon larval rearing has become necessary in order to grow these fish to fingerling size for release into natural waters from which they originate or for further cultivation to marketable size (Dabrowski et al., 1985). Larval rearing depends mainly on zooplankton groups like Cladocera, Artemia, Tubifex, Oligocheta and Chironomids larvae, but more recent work has shown that some sturgeon larvae could be grown exclusively on dry commercial diets. Results of rearing trials with Siberian sturgeon *(A. baerii*) have demonstrated that prepared diets can be used for intensive commercial culture from the onset of exogenous feeding (Beaulaton et al., 2005). Information on nutrition and feeding is scarce for most sturgeon species, being limited to and dealing mainly with the following species: Chinese sturgeon *(A. sinensis)* (Xiao et al., 1999), Lake sturgeon *(A. fluvescense)* (Dilauro et al., 1998), Beluga *(H. huso)* (Mohseni et al., 2005; Ebrahimi et al., 2006) and Persian sturgeon *(A. persicus)* (Pourali and Mohseni, 2006). In recent years many sturgeon hatcheries in the USA, Russia, Iran and Europe are using mixed feeding or only trout and sturgeon starter dry pellets to rear larvae. Sturgeon larval rearing is the first critical stage of sturgeon culture, so the feeding behavior must be studied very carefully.

Nutritional quality of the feed distributed to the fish larvae determines the success of the delicate larval rearing stage to a large extent. Moreover, nutritional quality of feed is certainly one of the major parameters, which must be determined in species exhibiting a high growth rate. This is necessary in order to avoid a restricted feeding level, which will frequently exacerbate growth heterogeneity and cannibalism (Awaiss and Kestemont, 1998). An important aspect of larval culture is the ability to provide feed that is able to sustain growth and development;

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hence, the formulation of specific dietary supplements designed to overcome nutrient deficiency or physiological requirements that may prevent or seriously stifle the successful culture of a target species (Leegender et al., 1995). Studies on specific nutritional needs of larval fish can be accomplished only when rearing of such fish is possible using semi-purified diets which give an acceptable performance (Dabrowski et al., 1985). Therefore, the aim of this study was to examine the effects of feeding live foods (Chironomids, Gammarid and Daphnia) with or without formulated diets on growth performance and survival in Beluga *(Huso huso)* larvae, and to reevaluate the optimal weaning period and the feeding regime in this species.

Materials and methods

Experimental Diets, Diet Formulation and Preparation

The following seven experimental diets were used; Daphina (DP), Chironomids (CH), Gammarid (G), Daphina + formulated diets (DPFD), Chironomids + formulated diets (CHFD), Gammarid + formulated diets (GFD) and formulated diets (FD). Live foods were obtained from Shahid Beheshti Hatchery, Rasht, Iran. Diets DPFD, CHFD and GFD were a mixture of live food and different levels of formulated diet (FD), which has been used with success for larvae of other species of sturgeon in this laboratory (Mohseni et al., 2006_a). Composition and proximate analysis of the basal formulated diet (microdiet) are shown in Table 1. The basal diets containing 48 -50% crude protein, 12-13% crude fat, 9-11% moisture and 8.5-9.5% ash were formulated using anchovy *(Clupeonella cultriventris)* fish meal as the main protein component together with a small amount (<10%) of soybean meal (Mohseni et al., 2006_a). The remaining protein source consisted of animal products. Dry ingredients were finely grinded (< 800 µm) in a Damico mill (Damicar Co., Mashad, Iran) and blended with the wet ingredients (corn and anchovy oil) using a twin-shell blender (Pooya Notash Machinery Co., Mashad, Iran) prior to being added to the main ingredient mixture. All ingredients were thoroughly mixed for 10 minutes in the Pooya mixer and steam-pelleted with a CPM meat grinder (California Pellet Mill Co., San Francisco, CA, USA).

Experimental Design and Maintenance of Fish

Ten thousand larvae of Beluga (two days old post hatch yolk-sac) were obtained from a local hatchery and transported to the International Sturgeon Research Institute, located 35km away from Rasht in northern Iran. Larvae were stocked in four 2000 liter fiberglass tanks for ten days. Feeding schedule of the different dietary regimes during the experimental period is shown in Table 2. Larvae were subsequently fed live food (including Artemia and Daphnia) for three days (from 12 to 15 days after hatching). After 3 days of feeding with live food, larvae were starved for 12 hours and 4662 larvae (mean weight 75.39±0.24 mg, n=50) were randomly captured from the stock tank and distributed into 21 smaller circular fiberglass tanks (100cm diameter, 50cm height, water depth 30cm and 300L water volume) at the density of 222 larvae per tank. Tanks were equipped with

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aeration, water renewal rate was 20%/h and water temperature was 17.2 ± 2.8 C. Dissolved oxygen level was 7.8±0.5 mg/l, pH 7.3± 0.2, CO_2 6 mg/l, alkalinity 157.5 mg/l, total hardness 360-400 mg/l and NH_4 0.1 mg/l. All tanks were maintained under natural photoperiod (LD 12:12). To prevent larvae from being flushed out through the central drain pipe, a plastic screen mesh (ca. 2 mm^2 for the first week and 9 mm^2 for the second and the third week) was wrapped around the drain pipe opening. Fish were fed seven experimental diets: Daphina (DP), Chironomids (CH), Gammarid (G), Daphina + formulated diets (DPFD), Chironomids + formulated diets (CHFD), Gammarid + formulated diets (GFD) and formulated diets (FD) in triplicate groups for 25 days. Live foods were obtained from Shahid Beheshti Hatchery, Rasht, Iran. Diets DPFD, CHFD and GFD were a mixture of live food and different levels of formulated diet (FD), which has been used with success for larvae of other species of sturgeon in this laboratory (Mohseni et al., 2006_a). For these three treatments, during the first 3 days of feeding (16-18 days after hatching), larvae were fed only live fish foods (DP, CH and G), but during the forth to sixth day of feeding (19-21 after hatching) larvae were fed 80% live food and 20% formulated diet. Subsequently, the FD content of the food was increased by twenty percent with a corresponding decrease in live food content every three days. Larvae were fed only FD from the 16^{th} day to the end of the experiment (Table 2). During the feeding trial, fish were hand-fed four times daily during the week (02:00, 08:00, 14:00 and 20:00 h) at 25%, 15%, and 10% body weight per day for the first, second, and third weeks of feeding, respectively. They were fed a larger starter feed at 3-5 % BW/day during the fourth week (Deng et al., 2003; Mohseni et al., 2006_b).Initially, Chironomids and Gammarid were finely cut but after 2 weeks, the whole body was offered. Daphnia was sieved through a net to get the suitable size for the mouth of fish. Each diet type was introduced to its respective tank from the 16^{th} day after hatching (four days after exogenous feeding started). Each day, before the first day-time feeding (8:00 h), the tanks and fecal collection columns were thoroughly cleaned with a brush to remove any residual particulate matter (faeces and uneaten feed), dead larvae were removed and mortality was recorded. During the experimental period, length and weight of fish were measured every four days and based on the results diets were adjusted for four subsequent days.

Analyses and Measurements

After 25 days of the feeding trial, fish were counted and weighed for determination of growth performance: weight gain (WG), specific growth rate (SGR), feed efficiency (FE) and survival. Proximate composition analyses of experimental diets and fish body were performed by the standard methods of AOAC (1995). Samples of diets and fish were dried to a constant weight at 105 ^oC for 6 hours. Ash content was determined by incineration at 550 ^oC; fat by soxhlet extraction using Soxtec system 1046 (Tacator AB, Hoganas, Sweden); and crude protein by the Kjeldahl method using a selenium catalyst (N × 6.25).

Statistical Analysis

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All data were analyzed by one-way ANOVA to test the effects of the dietary treatments. When a significant treatment effect was observed, Duncan's new multiple range test (Steel and Torrie 1960) was used to compare means. Treatment effects were considered at $P < 0.05$ level of significance. All statistical tests were performed using the SPSS statistical package (SPSS, version 12, Chicago, IL).

Results

The first signs of food granules were observed in the guts of the larvae at 10 h after the first feeding. All experimental groups were adapted to granulated diets on day 4-5. Live G and CH worms (cut into small pieces 2-3 mm in length), as well as DP were immediately accepted by sturgeon larvae whereas acceptance of the dry diet (FD) was delayed to a variable degree. Diets CHDF, GFD and DPFD were accepted 1.5-2 days later than live food, respectively; the 100% formulated diets (FD) even later (2-3 days later than CHDF, GFD and DPFD). Growth performance based on weekly analysis indicated that the best treatment for Beluga sturgeon larvae was Daphnia for the first week of feeding and Chironomids + formulated diets for weeks 2, 3 and 4. Between days 10 and 25, larvae fed diet CHFD (Fig. 1) had better growth performance than those fed live food and other treatments. Mortality during the experimental period showed a 10-15% rate over the first 3-5 days of exogenous feeding (Fig. 2). Growth performance and survival of Beluga fed the experimental diets are shown in Table 3. Growth performance and survival of Beluga larvae were significantly affected by the experimental treatments ($P<0.05$). Weight gain, SGR and FE of fish fed CHFD were significantly higher than those of fish fed the other diets ($P<0.05$). Also, WG and SGR of fish fed DP and CH were significantly higher than those of fish fed G, GFD and FD ($P<0.05$). However, there were no significant differences in WG and SGR among fish fed DP, CH and DPFD or among those fed G, DPFD, GFD and FD ($P>0.05$). Feed efficiency of fish fed DP, CH, and DPFD were significantly higher than those of fish fed G, GFD and FD; but there were no significant differences in this parameter among fish fed DP, CH and DPFD or among those fed G, GFD and FD ($P>0.05$). Survival of fish fed DP and CH were similar and significantly higher than those of fish fed G, DPFD, GFD and FD ($P < 0.05$). Survival of fish fed CHFD was not significantly different from that of fish fed DP and CH ($P>0.05$). Survival of fish fed G, GFD and FD were similar and significantly lower than those of fish fed the other diets ($P<0.05$). Whole-body carcass compositions of fish fed the experimental diets are presented in Table 4. Moisture content of fish fed G and GFD were similar and significantly higher than those of fish fed the other diets ($P<0.05$). There were no significant differences in moisture content of fish fed DP, CH, DPFD, CHFD and FD ($P>0.05$). Conversely, whole-body lipid content of fish fed DP, CH, DPFD, CHFD and FD were similar and significantly higher than those of fish fed G and GFD ($P<0.05$). There were no significant differences in whole-body protein or ash of fish fed all the experimental diets ($P>0.05$).

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Table 1: Composition of the basal formulated diet

Ingredients	g kg^{-1} dry diet
Fish mesh (anchovy fish)	410.5
Meat meal	100
Soybean meal	70
Dry milk	80
Yeast	80
Wheat flour	21.7
Starch	40
Sunflower oil	55
Fish oil	55
Molasses	20
Salt	15
Lecithin	2
L-Methionine	10
L-Lysine	10
Vitamin premix [a]	20
Mineral premix [b]	10
Vitamin C [c]	0.2
L-Carnitine [d]	0.6
Total	1000
Proximate composition [e]	(% , n = 3)
Moisture	10
Protein	49.5
Lipid	12.5
Ash	9

[a]Vitamin contents in g 100-1 premix: A, 160000 I.U.; D3, 40000 I.U.; E, 4 g; K3, 0.2; B1, 0.6 g; B2, 0.8 g; B3, 1.2 g; B5, 4 g; B6, 0.4 g; B9, 0.2 g; B12, 0.8 g; H2, 0.02 g; Ascorbic acid, 6 g; Inositol, 2 g; B.H.T., 2 g ; [b]Metal content in g 100-1 premix: Fe, 2.6; Se, 0.2; Co, 0.048; Cu, 0.42; Mn, 1.58; I, 0.1; Choline chloride, 1.2; [c]Lascorbyl-2-polyphosphate;

[d] Sigma, St Louis, MO, USA; [e]Mean proximate analysis (dry basis) for all eight diets. Samples for proximate analyses were analyzed in duplicate.

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Table 2: Feeding schedule of the different dietary regimes during the experimental period

Days after hatching	DP	CH	(G)	(DPFD)	(GFD)	(CHFD)	(FD)
16 – 18	100	100	100	100+0	100+0	100+0	100
19 – 21	100	100	100	80+20	80+20	80+20	100
22 – 24	100	100	100	60+40	60+40	60+40	100
25 – 27	100	100	100	40+60	40+60	40+60	100
28 – 30	100	100	100	20+80	20+80	20+80	100
31 – 33	100	100	100	0+100	0+100	0+100	100
34 – 36	100	100	100	100	100	100	100
37 – 39	100	100	100	100	100	100	100

Table 3: Growth and survival of Beluga sturgeon fry fed the experimental diets

Treatments	% WG[1]	SGR[2] (% day^{-1})	FE[3]	% Survival
(DP)	4547^{b}	15.4^{b}	286^{b}	94.9^{a}
(CH)	4380^{b}	15.2^{b}	283^{b}	90.4^{ab}
(G)	3953^{c}	14.8^{c}	260^{c}	78.2^{c}
(DPFD)	4209^{bc}	15^{bc}	278^{b}	88.6^{b}
(CHFD)	5162^{a}	15.9^{a}	297^{a}	91.7^{ab}
(GFD)	3978^{c}	14.8^{c}	262^{c}	81.6^{c}
(FD)	3894^{c}	14.7^{c}	255^{c}	64.4^{d}
[4]Pooled SEM	109	0.1	3.5	2.4

Means with same letter are not significantly different (Duncan's new multiple range test)

[1]WG % (weight gain %): (final weight-initial weight)× 100/initial weight

[2]SGR (% day^{-1}) = (Ln final weight – Ln initial weight)× 100 /day

[3]FE% (feed efficiency %): increase in biomass of fish - 100/dry feed fed

[4]Pooled standard error of mean: SD/√n

Table 4: Whole carcass composition (% wet weight) of beluga fed the experimental diets

Treatments	% Moisture	% Protein	% Lipid	% Ash
(DP)	78.1^{b}	17.3	2.2^{a}	1.2
(CH)	76.9^{b}	17.4	2.3^{a}	1.32
(G)	83.8^{a}	17.3	1.5^{b}	1.3
(DPFD)	77.3^{b}	17.3	2.2^{a}	1.3
(GFD)	85.2^{a}	17.4	1.3^{b}	1.27
(CHFD)	79.1^{b}	17.3	2.3^{a}	1.3
(FD)	78.6^{b}	17.4	2.3^{a}	1.35
Pooled SEM	0.76	0.06	0.09	0.02

Means with same letter are not significantly different (Duncan's new multiple range test)

Pooled standard error of mean: SD/√n

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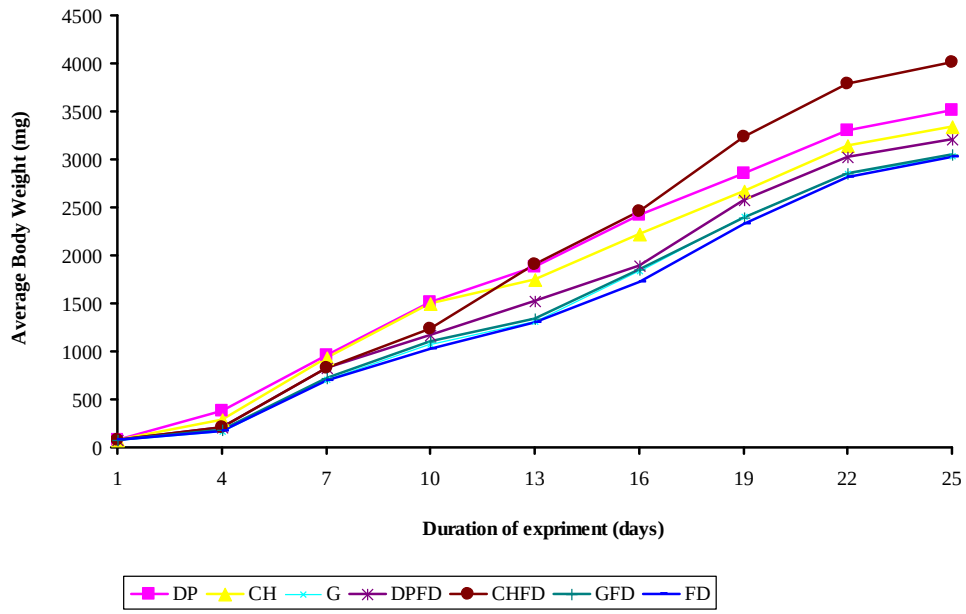

Figure 1: Growth patterns of Beluga larvae fed six different starter diets over a period of 25 days

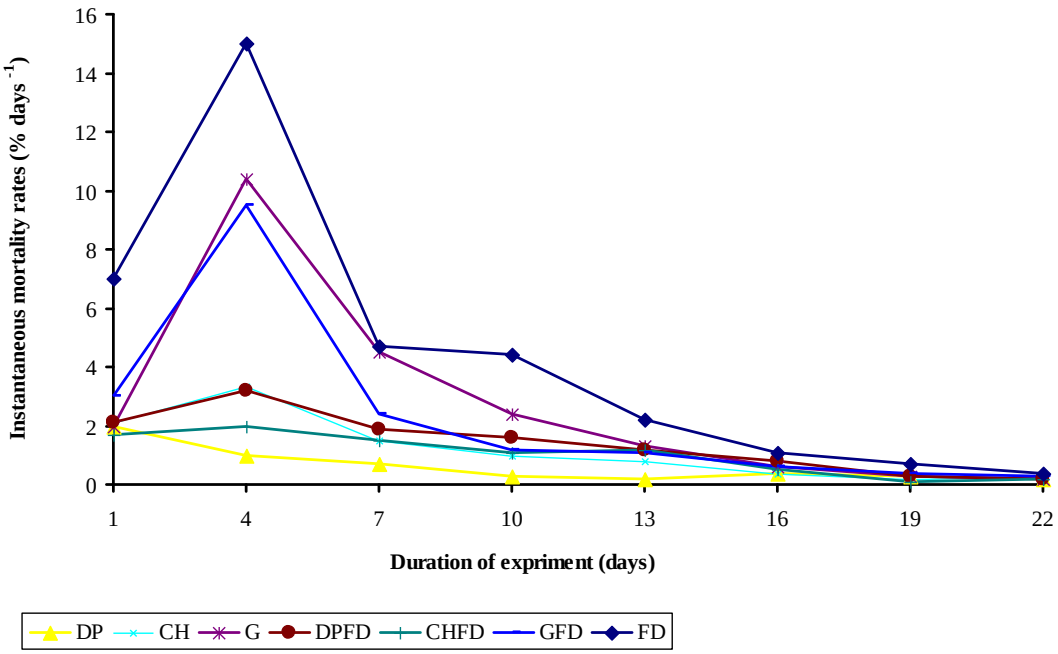

Figure 2: Instantaneous mortality rates of Beluga larvae calculated for 25 days duration

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Discussion

In this study live Daphnia, cutted Gammarid and Chironomid worms were immediately accepted by 16 days old sturgeon larvae; whereas acceptance of 100% dry diet was delayed to a variable degree. The major problem in larviculture lies in the choice of good-quality food which is acceptable to the fish species of interest. According to the present study, larval rearing of Beluga can be carried out successfully with a mixed diet from the time of hatching onwards. The comparatively low survival and growth rates of Beluga larvae fed a formulated diet in this study could be attributed to the fact that the stomach of this fish is not developed enough to handle this type of feed in the first week after hatching. The stomach only becomes functional a few days after hatching. The result obtained by Pooling et al., 1988 showed that the use of Artemia naupli or zooplankton in larviculture in African catfish (*Clarias gariepinus* Burchell) allowed excellent survival rates. In our trial, acceptance of the formulated diet and performance of fish fed the diet seemed to be relatively low. Also, results indicated that Beluga larvae prefer Daphnia, Chironomids or a mixture of Chironomids and a formulated diet to Gammarid, alone or mix with a formulated diet. The acceptance of these diets may be due to their composition, texture, flavour or a mixture of these factors. Interestingly, the mixture of Chironomids and formulated diet gave better growth than the live food alone. It is not clear whether there are any interactions between some components of the formulated diet, the live food and the nature of such interactions. This needs to be researched on. But in any case, it is a double gain, obtaining better growth with less inclusion of live food. Culture of live food is relatively demanding; hence a regime that includes some formulated diet and has no adverse effect on the performance of larvae would be more economical than the use of live food itself. Since a commercial diet specifically formulated for sturgeon is not easily available, other starter feeds including commercial non-purified trout diets and starter marine diets are commonly used. Periods of food deprivation or inadequate nutrition have been shown to result in abnormal behavior and morphological development (such as bending of the spinal cord, hunched back (Mohseni, 1995) and other nutrition disorders (Hung and Deng 2002; Hung 1991). The mixture of formulated diet and Daphnia or Chironomid gave good performance in Beluga larvae in this trial and there were no abnormal behaviors or morphological development. Growth of fish in the present study is similar to data from other works. Monaco et al. (1985) and Buddington and Doroshov (1984) achieved less weight gain (3.7-5.7$_g$) after 42 days of feeding Californian sturgeon of initial weight between 42 and 46 mg.

The results showed that the availability of planktonic and benthic organisms to fingerling sturgeon is variable and depends on the behavioral peculiarities of both. The rates of consumption of Daphnia and Chironomid larvae were different. The Chironomid larvae were eaten completely, but only around 85% and

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68% of Daphnia and Gammarid respectively, were eaten and those eaten were only near the bottoms of the tanks (personal observation). Furthermore, the results showed that Beluga *(H. huso)* fry prefer Chironomids to planktonic organisms, but more investigations are required. Growth performance based on weekly analysis indicated that the best treatment for Beluga sturgeon larvae was Daphnia for the first week of feeding and Chironomids + formulated diets for weeks 2, 3 and 4. Between days 10 and 25, larvae fed diet CHFD (Fig. 1) had better growth performance than those fed live food and other treatments.

Survival of larval and fry sturgeon at the first-feeding stage is much lower than that of many other freshwater farmed fish. Low fry survival is generally ascribed to fish husbandry practices, especially feeding practices. However, diet quality may also be a determinant of sturgeon fry survival. The use of Artemia and Daphnia as living prey has been widely discussed during the past decade, and they are the most common living natural food used during the first month of rearing to start fish larviculture in Iranian sturgeon hatcheries. They are then efficiently replaced by other zooplanktonic groups or by dry diet. However Szlaminska and Przybil (1986) noticed that a mixed diet composed of living prey and inert food in variable proportions gave better results: distributed in small quantities, the zooplankton provided some nutrients necessary for the development and growth of the larvae. In practice, this mixed feeding period is largely used in marine fish to train the larvae to accept dry diet and is considered an ideal practice during the preconditioning period (Rosenlund, 1995). Beluga larvae fed the mixture of Chironomids and formulated diet (CHFD) in this feeding trial had as good survival as those fed live prey (Daphnia or Chironomids). It may also be beneficial to feed Daphnia rather than live Gammarid to first-feeding Beluga fry, because Daphnia nauplii could be cultured in earthen ponds prior to sturgeon spawning and hatching activities.

In our study, all formulated diets tested with different levels of Daphina, Chironomids and Gammarid performed well as first feed for Beluga sturgeon fry (personal observation). However, for Gulf sturgeon, formulated feed was poorly accepted by first-feeding larvae and resulted in more than 99% mortality by the third week of feeding (Bradi et al., 1998). This is contrary to our results with formulated diet, which showed 10-15% mortality over the first 3-5 days of exogenous feeding (Fig. 2). Although live Chironomids and Daphnia provided reliable growth and survival for first feeding Beluga sturgeon, we found daily culture and feeding of 100% live Chironomids and Daphnia to be labor intensive for rearing large numbers of fry. It would be advantageous for the culturist to reduce the live feeding period by using stocking densities that allow fry to reach a minimum size for efficient conversion to formulated diets as quickly as possible. But late initiation of feeding was preceded by increase in larval mortality. During the first week of feeding, on day 3, mortality of fish fed

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FD was higher than mortality for the rest of the treatments. Slightly lower values were recorded in fish fed G and GFD. Mortality was low and decreased, as the larvae grew larger during the first 2 weeks after initiation of feeding (Fig. 2). Low mortality was reported (5.7%) by Deng et al. (2003), but much higher mortality (23.6-31.4%) was reported by Herold (1996) in three different studies where the larvae were fed a commercial feed for the first 24 days after initiation of feeding. Higher mortality (ca. 16.6%) was reported in Siberian sturgeon larvae (22 days post hatch and 13 days after initiation of feeding) (Gisbert and Williot, 1997). The survival of Lena River sturgeon during the first month of rearing, when fed dry diets, was 81-85% (Dabrowski et al., 1985). Semenkova (1988) noticed an initial mortality of 10-14% in *A. baeri stenorhynchus* during the commencement of feeding. Buddington and Doroshov (1984), on the other hand, did not record any mortality up to 16 days after hatching in California sturgeon larvae kept at 16-17 C. The highest larval mortality in the present study typically occurred in larvae fed FD in the first week after initiation of feeding, maybe due to the structure of the food. A lot of food was distributed on the surface of water and larvae were deprived of this food. Thus, the mortality observed during the present trial was caused by the kind of food; the change from endogenous to exogenous feeding being less important. More cannibalism was observed in larvae fed diets GFD and FD compared to those fed other diets. From treatments GFD and FD, 7.5 and 10.7% of fish, respectively were missing. Similar observations have been reported for white sturgeon larvae deprived of feed or offered poor quality feeds (Gawlicka et al., 1996; Deng et al., 2003). This is particularly true in the present study due to the small particle size of feeds, which tended to float on the surface for an extended period of time. Only when the incoming water from the spray bar hit the feeds or the feeds absorbed enough water to sink, did the feed become available to the bottom feeding sturgeon. Too high a water flow rate and too large a screen mesh size increased the amount of feed flushed out and thus unavailable to the larvae.

Whole body percent moisture and lipid of larvae fed G and GFD were significantly higher and lower, respectively than those of larvae fed the other diets. Sturgeon whole-body proximate composition is given on a wet weight basis to avoid erroneous conclusions, as explained by Shearer (1994). A strong reverse relationship between whole-body water content and whole-body lipid content was observed in rainbow trout ($r_2 = 0.877$) (Shearer, 1994), Persian sturgeon (Mohseni et al., 2007) and gilthead sea bream (Sparus aurata) ($r_2 = 0.973$) (Jobling, 2001).

We found that first-feeding Beluga sturgeon *(Huso huso)* fry must attain a minimum size of 30-35 mm TL and 60-80 mg to be converted to formulated (dry) diet with least mortality. The digestive system and olfactory organs of fish at this stage of growth were fully developed and played a vital role in the fish's search for food

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particles. Use of acceptable Chironomide or Daphina + formulated diets in the first week of feeding, right from the beginning of exogenous feeding of Beluga larvae has proved to be successful here. It is firmly believed that by improving the feeding strategy and particle size of feed, survival of reared sturgeon can be further enhanced. GFD were shown to be less efficient than the diet based on CHFD and DPFD.

A comparison of mean weights at the first week shows that larvae fed live Daphnia and Chironomid worms had significantly higher weights than the other groups. The earlier initiation of feeding gave these groups a definite advantage over the other test groups. This becomes evident when the growth performance is compared for the intermediate periods. Although diets tested in the present study were almost isonitrogenous (Table 1), the weights of fish fed these diets differed significantly after 24 days of rearing (Table 3). Between days 10 and 24 (Fig. 1), larvae fed CHFD had better growth performance than those fed live food and other treatments.

In summary, these results indicated that the mixture of Chironomid and formulated diet (CHFD) could be the best food for Beluga larvae based on WG, PER, FE and whole-body proximate composition of larvae. Also, these results may show the importance of live food soon after hatching followed by formulated diets in a gradual application pattern, as early as on the fourth to fifth day after hatching. To the best of our knowledge, there is little study on larvae culture for this species, which has a tremendous culture potential particularly in temperate countries. More detailed studies on nutrient requirement and digestibility are required so as to formulate low-cost practical diets for this species.

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References

AOAC, 1995. Official methods of analysis of AOAC International. AOAC International, Arlington, VA.

Awaiss, A. and Kestemont, P., 1998. Feeding sequences (rotifer and dry diet), survival, growth and biochemical composition of African cat fish, *Clarias gariepinus* Burchell Pisces: *Clariidae*), larvae. *Aquaculture Research*, 29, 371-741.

Bai, S. C., Young, T. C. and Xiaojie, W., 2001. A preliminary study on the dietary protein requirement of Larval Japanese Flounder, *paralichthys olivaceus*. *North American Journal of Aquaculture*, 63, 92–98.

Sungchul C. Bai and Yong-Taeg Cha, 1997. Comparison of Growth and Body Composition in Olive Flounder Larvae (*paralichthys olivaceus*) Fed Domestic Experimental and Imported Commercial Microparticulated Diets, *Journal of Aquaculture*, 10(**1**), 87-95. (in Korean with English Abstract).

El-Saidy, D. M. S. D., K. Dabrowski, and Bai, S. C., 2000. Nutritional effects of protein source in starter diets for

[DOR: 20.1001.1.15622916.2012.11.1.10.6]

channel catfish in sub-optimal water temperature. *Aquaculture research*, 31, 885-892.

Beaulaton, C., Heather H. J. Michaels, J. and Main, K., 2005. The effects of four commercial larval diets on the growth and survival of Siberian Sturgeon *(Acipenser baeri).* Aquaculture America, New Orleans Louisiana. Pp.**9**.

Bradi, R. W., Chapman, F.A. and Barrows, F. T., 1998. Feeding trials with hatchery- produced Gulf of Mexico sturgeon larvae. *Progressive Fish Culturist*, 60, 25-31.

Buddington, R. K. and Doroshov, S. I., 1984. Feeding trials with hatchery produced white sturgeon Juvenile (*Acipenser transmontaus*). *Aquaculture*, 36, 237-243.

Chau, C. and Zambonini Infant, J. S., 2001. Substation of live food by formulated diets in marine fish larvae. *Aquaculture*, 200, 161-180.

Dabrowski, K., Kaushik, S. J. and Fauoconnea, B., 1985. Rearing of sturgeon (*Acipenser baeri* BRANDT) larvae I. Feeding trial. *Aquaculture***,** 47, 185-192.

Deng, D. F., Koshio, S., Yokoyama, S., Bai, S.C., Shao, Q., Cui, Y. and Hung, S. S. O., 2003. Effects of feeding rate on growth performance of white sturgeon (*Acipenser transmontanus*) Larvae. *Aquaculture*, 217, 589–598.

DiLauro, M. N., Krise, W. F. and Fynn-Aikins, K., 1998. Growth and survival of lake sturgeon larvae fed formulated diets. *Progressive Fish Culturist*, 60, 293-296.

Ebrahimi, E. and Zare, P., 2006. Growth and survival of Beluga (*Huso huso*) and Persian surgeon (*Acipenser persicus*) fingerlings fed by live food and artificial diet. *Journal of Applied Ichthyology*, 1, 321-324.

Gawlicka, A., McLaughin, L., Hung, S.S.O. and la Noue, J., 1996. Limitation of carrageenan micribound diets for feeding white sturgeon larvae. *Aquaculture*, 141, 254-265.

Gisbert, E. and Williot, P., 1997. Larval behavior and effect of the timing of initial feeding on growth and survival of Siberian sturgeon (*A. baeri*) larvae under small scale hatchery production. *Aquaculture*, 156, 63-76.

Herold, M. A., 1996. Lipid nutrition in white sturgeon *(Acipenser transmontanus*) larvae during ontogeny. PhD Thesis, University of California, Davis 204pp**.**

Hung, S. S. O., 1991. Nutrition and feeding of hatchery-produced Juvenile white sturgeon *(Acipenser transmontanus)*: an overview. In: Acipenser. P. Williot (Ed.). Proc. First International Symposium of Sturgeon, France. pp. 65–77.

Hung, S. S. O. and Deng, D. F., 2002. Sturgeon, *Acipenser* spp. In : Webster, C.D., Lim. C (Eds.), Nutrient requirement and feeding of finfish for aquaculture. CABI Publishing, Wallingford, UK, pp. 344-357

Jobling, M., 2001. Nutrient partitioning and the influence of feed composition on body composition. In: Food intake in fish. D. Houlihan, T. Boujard, M. Jobling (Eds). Blackwell Science, Oxford, England. pp. 354–375.

Leegender, M., Kerdchuen, N., Corraze, G. and Bergot, P., 1995. Larvai rearing of an Artificial cat fish Heterobranchus longifilis (Teleostie, Clariidae): Effect of dietary lipids on growth, survival and fatty acid composition of fry. *Aquatic Living Resource*, 8, 351-363.

Mohseni, M., 1995. A study on the effects of environmental factors such as increase in stocking density of eggs larvae of Great sturgeons produced through artificial propagation, on the appearance of morphological abnormalities. MSc Thesis. Tehran University, 103pp [In Persian].

Mohseni, M., 2008. The potential for sturgeon Aquaculture, Current Situation and some achievement information in Iran. Domestic workshop on aquaculture development in Korea. Ungcheon - Korea. 76-106

Mohseni, M., Pourkazemi, M., Bahmani, M., Salehpour**, M., Pourali, H. R. and Hadadimoghadam K. , 2005.** Rearing Beluga *(Huso huso)* in earthen ponds and fiberglass tanks. *Iranian Scientific Fisheries Journal*, 1, 119-132 [In Persian].

Mohseni, M., Bahmani, M., Pourali, H.R., Mahbubi Sufiani, N., Haghighiyan, M., Zahedifar, M. and Jamalzad, F., 2006$_a$. Determining nutritional requirements in Beluga *(H. huso)* from Larval stage up to marketable size. Iranian Fisheries Research Organization. pp. 241.[In Persian]

Mohseni, M., Bahmani, M., Pourkazemi, M., Pourali, H. R. and Arshad, U., 2006$_b$. Determination of the best feeding ratio in Beluga *(Huso huso)* meat production cultured in fiberglass tanks. *Iranian Scientific Fisheries Journal***,** 4, 165-180 [In Persian].

Mohseni, M., Sajjadi, M. and Pourkazemi, M., 2007. Growth performance and body composition of sub-yearling Persian sturgeon (*Acipenser persicus*, Borodin, 1897) fed different dietary protein and lipid levels. *Journal of Applied Ichthyology*, 23, 204-208.

Monaco, G. R., Budington, K. and Doroshov, S. L., 1985. Growth of white sturgeon (Acipenser transmomtanus) under hatchery conditions. *Journal of World Mariculture Society*, 12, 113-121.

Pooling L., Schoonbee, J., Prinsloo, H. and Wild, A. J. B., 1988. The evaluation of live feed in the early larval growth of the sharptooth catfish (C. gariepinus). *Water South Africa*, 14, 19-24.

Pourali, R. H. and Mohseni, M., 2006. Survival and growth rates of larval and juvenile Persian sturgeon *(A. persicus)* using formulated diets and lives food. *Journal of Applied Ichthyology*, 22, 303-306.

Rosenlund, G., 1995. Co- feeding marine fish larvae with inert diets. In: LARVI 95: Fish and Shellfish Larviculture Symposium (ed. By P. Lavense, E. jaspers and I. Roelants), p.267. Special Publication No. 24, European aquaculture Society, Gent.

Semenkova, T. B., 1988. Growth Survival and physiological indices of juvenile Lena river sturgeon, *Acipenser baeri stenoorhynchus* A. Nikolsky, grown on food, Ekvizo. In: I.N. Ostroumova (Editor), Problems of fish physiology and nutrition. Ministry of fish management, Leningrad, 194,107-111.[In Russian]

Shearer, K. D., 1994. Factors affecting the proximate composition of cultured fishes with emphasis on salmonids. *Aquaculture*,119, 63–88.

Steel, R. G. D. and Torrie, J. H., 1960. Principles and Procedures of Statistics. McGraw- Hill, New York, NY, 481pp.

Szlaminska, M. and Przybil, A., 1986. Feeding of carp (*Cyprinus carpio*) larvae with an artificial dry food, living zooplankton and mixed food. *Aquaculture*, 64, 77-82.

Xiao, H., Cui, Y., Hung, S. S. O., Zhu, X., Zou, Z. and Xie, S., 1999. Growth of Juvenile Chinese sturgeon (*Acipenser sinensis*) grew fed live and formulated diets. *North American Journal of Aquaculture*, 61, 184-188.

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