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Review Article

Recent advances in sturgeon nutrition

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ABSTRACT

Sturgeons are fish species of biological and economical importance, and most of them are endangered, vulnerable or rare because of their large size, late sexual maturity, long period between spawning, and longevity. These unique biological characteristics make them highly susceptible to overfishing, degradation of habitat and spawning ground, and contamination of water and sediments by pollutants. The objective of the current review is not to exhaustively include all studies on sturgeon nutrient requirements and utilizations conducted under laboratory conditions, but to critique some studies and update previous reviews. The goal is to provide a basis for recommendations for future research so that these important fish species can be managed and produced sustainably. Energy, protein, lipid carbohydrate, vitamin, and mineral requirements and utilizations were reviewed or critiqued. Future studies to develop suitable chemically defined diets to support good growth of sturgeon are urgently needed. Furthermore, future experiments should be designed systematically with more consideration on within and among studies and within and among different species of sturgeon. Finally, future experiments should be designed with a systematic approach with multiple doses (inputs) and multiple responses (outputs) at several levels of hierarchical organization in a biological system using traditional biochemical and modern molecular techniques and computer modeling with proper experimental design and methodology. This approach will provide a more realistic and holistic understanding of the mechanisms of nutrient requirements and utilizations, which will help us better manage wild sturgeon stocks and produce sturgeon more efficiently and sustainably under aquaculture conditions.

1. Introduction

Sturgeons are species of biological (evolutional, geographical, morphological, anatomical, and physiological) and economical (ecological, recreational, and aquacultural) importance. These species belong to the phylum Chordata, superclass Osteichthyes, class Actinopterygii, order Acipenseriformes and family Acipenseridae. There are 27 species in the Acipenseridae family, but 4 species are extinct (Birstein, 1993). The 23 extant species are grouped into 4 genera with 2 species in *Huso,* 2 species in *Scaphirhynchus*, 3 species in *Pseudoscaphirhynchus* and 16 species in *Acipenser* (Scott and Crossman, 1973). These fishes evolved 250 million years ago in the Jurassic period and are considered genetically "living fossils" (Birstein, 1993; Billard and Lecointre, 2001). Furthermore, sturgeons maintain many primitive characteristics, such as a heterocercal caudal fin, a cartilaginous skeleton, a notochord in adults, and 5 rows of bony dermal plates (scutes) in the longitudinal body (Scott and Crossman, 1973). These fishes are also unique that they have a high capacity for hybridization, and in sympatric distribution nearly all species will hybridize (Billard and Lecointre, 2001). Sturgeons mainly live in temperate waters (from subtropical to sub-Arctic) of the Northern hemisphere; some grow and sexually mature in marine and brackish waters but migrate to freshwater to spawn, while others are land locked in freshwater for their entire life cycle (Billard and Lecointre, 2001).

Beluga sturgeon (*Huso huso*) in the Black, Caspian, and Azov Seas is the largest freshwater fish, which can reach a maximum weight of 1,000 kg, and shovelnose sturgeons (*P. kaufmanni, P. hermanni*, and *P. fedtschenkoi*) in the Aral Sea are the smallest sturgeons with a

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Table 1
Macronutrient requirements of different species of sturgeon.

Nutrients	Rainbow trout[1]	White sturgeon	Siberian sturgeon	Chinese Sturgeon	Persian Sturgeon	Beluga sturgeon	Stella sturgeon	Lake sturgeon	Adriatic sturgeon	Amur sturgeon	Russian sturgeon	Hybrid sturgeon
DP/DE, kcal/kg	4,200	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Protein, %	38	40[2]	42[3]	40–45[4]	40[5]	NT	NT	NT	NT	NT	NT	37[6]
Fatty acid, %												
18:3 (n-3)	0.7–1.0	R[7]	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
n-3 LC-PUFA	0.4–0.5	R[7]	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
18:2 (n-6)	1.0	R[7]	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Cholesterol	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Phospholipid	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT

DP = digestible protein; DE = digestible energy; NT = not tested; R = required.
[1] NRC, 2011 and listed as a reference.
[2] Moore et al. (1988).
[3] Médale et al. (1995).
[4] Xiao et al. (1999).
[5] Mohseri et al. (2007).
[6] Guo et al. (2012).
[7] Deng (1996).

maximum weight of 0.5 kg (Doroshov, 1985). These fishes usually have a subcylindrical body, an extended hard snout, and a ventral protrusible mouth with barbels (Billard and Lecointre, 2001). They are excellent bottom-feeders because they have very sensitive barbels on the underside of their snouts to detect bottom animals and their long and protruding mouth to suck up prey. The gastrointestinal tract of sturgeons is also very unique because their pyloric stomach walls are hypertrophied into a gizzard-like organ, the intestines of adult sturgeons have a functional ciliated epithelium, and their hindguts are modified into spiral valves (Buddington and Doroshov, 1986).

Over 80% of the existing sturgeon species are endangered, vulnerable, or on the brink of extinction (IUCN Red List, 2017) because of their late sexual maturity (3 to more than 20 years) and long period between spawning (2 to more than 5 years) in the wild (Birstein, 1993; Billard and Lecointre, 2001). Furthermore, their large size (3 kg to over 2,000 kg) and longevity (3 years to over 100 years) make them very susceptible to overfishing, degradation of habitats and spawning grounds, and contamination of water and sediments by pollutants (Billard and Lecointre, 2001). Many species of sturgeon are currently being cultured for release to the wild to augment natural populations or are produced by aquaculture for human food consumption to relieve the fishing pressure on their wild stocks (Billard and Lecointre, 2001; Bronzi et al., 2011).

The objective of the current review is not to exhaustively include all studies on sturgeon nutrient requirements and utilizations conducted under laboratory conditions, but to critique some studies and to update previous reviews (Hung, 1988, 1991a,b; Médale et al., 1995; Hung and Deng, 2002; García-Gallego et al., 2009). Furthermore, despite considerable global interest in sturgeon aquaculture, there is still a paucity of information on sturgeon nutrient requirements and utilizations, and even on the general nutrition of sturgeons (Tables 1–4); this information is urgently needed for success in culturing these species of fish. The ultimate objective of this review is to encourage and to provide a basis and rationale for recommendations for future research so that these important fish species can be managed and produced sustainably.

2. Energy

To our knowledge, the only energetic studies that have determined the relationships among several components of the energy budget in sturgeons were conducted by Médale and Kaushik (1991), Médale et al. (1991), Cui et al. (1996), and more recently by Guo et al. (2012). Médale and Kaushik (1991) studied the energy utilization of 40-, 230-, and 1,500-g Siberian sturgeon (*Acipenser baerii*) using a trout feed with 50% crude protein, 11% fat, and 21.5 kJ/g dry diet. These authors found that feed intake decreased with size. Energy retention (ER) was higher in the 1,500-g sturgeon (55% as body lipid) than in the 40- and 230-g sturgeon, which retained energy mainly as body protein. Endogenous nitrogen loss was 60 mg/kg BW per day in sturgeon fasted for 4 weeks. As noted by the authors, a limitation of this study was the discrepancy between the comparative slaughter and the indirect calorimetric methods. A better indirect calorimetry similar to that used by Gisbert et al. (2001) should be used in future energetic studies of sturgeons with the comparative slaughter method.

Médale et al. (1991) studied the utilization of dietary non-protein energy in the Siberian sturgeon (initial body weight [IBW] = 49 g) using 2 dry diets (51% crude protein and 22 kJ/g dry diet) containing either 21.8% lipid and 9.9% crude starch or 12.5% lipid and 20% highly digestible starch. The sturgeon were fed 8 weeks of the 2 diets, and those fed the 21.8% lipid and 9.9% crude starch diet had lower specific growth rate (SGR), SGR = (ln FBW- ln IBW)/Days, where IBW and FBW were initial and final body weights, respectively, and feed efficiency (FE), FE[1] (%) = 100 × Wet weight gain/Weight dry feed fed, than those fed a diet with 12.5% lipid and 20% highly digestible carbohydrate. These authors reported that digestible energy was higher in the sturgeon fed the diet containing lower lipid and higher digestible carbohydrate. The increase in digestible energy resulted from an increase in body lipid in the sturgeon, while urinary and gill energy[2] were not different in sturgeon under the 2 dietary treatments. Fecal energy was higher in sturgeon fed the low-lipid and high-digestible carbohydrate diet. These results suggested that dietary lipid is a better energy source than carbohydrate to spare dietary protein in Siberian sturgeon. This study, however, used not only 2 diets with 2 levels of lipid but also 2 sources and 2 levels of carbohydrates; thus, the conclusions drawn tend to be very general. Future studies should be conducted using dose–response methods with a more graded level of a single source of dietary lipid, protein, and carbohydrate, similar to those used by Guo et al. (2012) so that a better cause-effect relationship can be established among the different energetic components in the sturgeon.

[1] To maintain consistency in the review, some of the feed efficiency values were re-calculated from the feed: gain ratio or feed conversion efficiency from the original reports.
[2] Definitions of different energy components of fishes can be found in NRC (1981) and Chapter 4 of NRC (2011).

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