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Effect of Temperature on Sperm Motility in Fishes - A Review

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ABSTRACT

Sperm motility is an important factor used to assess sperm quality. Sperm motility is influenced by many factors. Temperature plays an influential role in sperm motility. In the present study, an attempt has been made to review the available literature & research articles on the influence of temperature on sperm motility in fishes. The study reveals that sperm motility, fertilizing ability, velocity and the duration of the motility period, depends on the temperature.

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INTRODUCTION

The success of fertilization in breeding programs in fishes is dependent on the quality of sperm. The quality of sperm is affected by various endogenous and exogenous factors. Primary factors such as the paternal genetic heritage (Simmons, 2005), the spermiation period and sperm storage conditions in the testes, as well as the favorable environmental conditions during motility activation (Billard, 1986), affects the quality of sperm. The main prerequisite for evaluating the quality and fertilizing ability of semen is sperm motility (Billard, 1978; Stoss, 1983).

Sperm motility is the most evaluated criteria for sperm quality assessment in fish due to its correlation with fertility (Rurangwa *et al*., 2001).

Sperm motility is affected by several parameters like temperature, pH, ions and their concentrations, osmolality and dilution (Stoss, 1983; Billard *et al.*, 1995a; Cosson *et al.*, 1999; Morisawa 1999; Cosson, 2004; Alavi 2011). Temperature is one of the most significant environmental factors influencing aquatic life and processes. Seasonal variations in this parameter and the photoperiod signal can regulate the sexual maturation process (Dorts *et al.*, 2012, Kraak and Pankhurst 1997). Too much low, as well as too much high temperature affect sperm motility (Lahnsteiner and Mansour 2012).

In this context, an attempt has been made to review the available literature & research articles on the influence of temperature on sperm motility in fishes.

Effect of temperature

The duration of motility, fertilizing capacity and velocity of spermatozoa is affected by the temperature of the activation medium (Ginzburg, 1968; Stoss, 1983; Billard *et al.*, 1995a) and of that of the brood stock holding tank (Williot *et al.*, 2000). Since the energetic resources of fish spermatozoa are very limited, the rise in temperature may result in increase in velocity but leads to a shorter duration of motility, and conversely, lowering the temperature results in a greater motility duration and reduced cell velocity (Schlenk and Kahmann, 1938; Ginzburg, 1968; Stoss, 1983).

Salmon & Trout

Temperature plays a significant role in total duration and period of progressive movement in fishes. In the sperm of salmonids, temperature affects the sperm beat frequency (Cosson *et al.,* 1985). In trout, greater the temperature greater was the beat frequency and but lower was the duration of forward movement (Billard and Cosson, 1992). In try out lower, the temperature greater was the duration of sperm movement (Van Look, 2001).

At temperatures of 12.5°C and 16°C, the forward motion of spermatozoa 4 seconds after their activation by water in *Salmo trutta m. fario* was 160- 164/ µ /sec. After 8 seconds it reduced to 85-91 / µ /sec, after 16 seconds it further slowed down to 24-33 / µ /sec and after 26 seconds to 2-5/ µ /sec. The forward motion ceased within 29 seconds after activation of the sperm by water (Schlenk and Kahmann, 1938).

In lake trout *Salvelinus namaycush* forward movement stopped completely within 29 sec at 12.5-16°C and within 56 sec at 2.25°C. However, the total distance covered by the spermatozoa hardly changes, 2.3 mm on the average, varying from 2 .0 mm at highest temperatures to 2 .6 mm at 2. 25°C and 6.0°C (Schlenk and Kahmann, 1938).

The flagellar beat frequency of spermatozoa rainbow trout was measured at different temperatures (Billard and Cosson, 1988, 1992). The beating frequency was low at 5 °C, remained stable up to 10 °C, followed by a rapid rise at about 14 °C and further stabilized at values above 21 °C.

Temperature also influenced the beat frequency of de-membrane and ATP reactivated spermatozoa. The initial frequencies increased with temperature. The recorded frequencies were 25 Hz at 5 °C, 45 Hz at 15 °C and more than 80 Hz at 25 °C (Billard and Cosson, 1988). These values were same in live spermatozoa between 5 and 20 °C, but at 25 °C, the beat frequency in live spermatozoa was 50 Hz, while it was 80 Hz in de-membrane sperm reactivated in the presence of 1 mM ATP. These studies point out the negative consequences of ambient temperature (Billard and Cosson, 1988, 1992; Cosson *et al.,* 1991). Cosson *et al.,* (1985) also studied the effect of temperature on the rate of decline in beat frequency as a function of time after activation.

In *Salmo irideus* at temperatures of 13 °C the duration of motility was 60-105 s while the duration of energetic movement was 20-45 s (Dorier, 1951).

Cyprinids

The maximum duration of motility in carp spermatozoa was obtained at 10°C (Lal 1996). After post-activation, the total duration of motility of spermatozoa of *Cyprinus carpio* at 20-21°C was 70-80s (Jezierska and Witeska 1999) and as 120s by Elster and Mann (1952). The duration of motility of spermatozoa of grass carp was shorter than the common carp (Belova, 1981; Jezierska and Witeska, 1999). Spermatozoa exhibited longer motility at 20°C than at 26 or 30°C in both common and grass carps (Jezierska and Witeska, 1999). Billard and Cosson (1989) reported that the total motility duration in carp was longer than in trout. In carps, the beat frequency of the majority of spermatozoa also declined progressively after activation within 80-90s (Billard and Cosson, 1992; Billard *et al.*, 1995b).). Studies also point out that motility of spermatozoa of *Cyprinus carpio* stored at 2 or 5°C is much longer than at 22°C (Ravinder *et al.*, 1997). Longer duration of motility was also reported at low temperatures other cyprinids also, *Puntius filamentosus* at 10°C and *Amblypharyngodon mola* at 20°C (Paul and Jayaprakas, 1996). Maximum motility duration was recorded at 5°C for *Puntius sarana* and 10°C for *Labeo fimbriatus* (Bindu 1999). In *Barbus conchonius* rise in temperature increased the sperm motility and viability. 34°C was the optimum and it recorded viability of 556s and after which motility and viability declined (Thamizhselvi 2014).

Osphronemus, Etroplus, Anabas and Catfish

Bindu (1999) reported that in *Osphronemus goramy*, the mean duration of motility at 5°C was 60.76s. Maximum duration of motility 74.76s was recorded at 15°C, thereafter a gradual reduction in motility was seen. Minimum duration of motility was recorded at 35°C (11.56 s). *Etroplus suratensis* exhibited longer duration of motility of spermatozoa at low temperatures. Maximum motility duration was recorded at 5°C (Bindu 1999). In *Anabas testudineus* maximum duration of motility was observed at 4°C (Sheeja 1994 and Sammud *et al.*, 2011). Low temperature of (4ºC) extended the motility and viability of spermatozoa compared to the culture temperature (25ºC) in African catfish (Mansour *et al.*, 2002).

Sturgeon

In *Huso huso*, the deceleration was very slow. The maximum speed of spermatozoa was lower than in trout. During the first seconds after activation by water, the speed recorded was 100/ μ /sec at 16.2°C. Two minutes after water was added, many spermatozoa still moved at a speed of 72/ μ /sec. But after 5 minutes the speed was reduced to 16/ μ /sec, after 7-13

minutes only a few spermatozoa moved at no more than 10/ μ /sec, and finally, all movement stopped within 14-15 minutes (Ginzburg, 1959).

In cultured Siberian sturgeon *Acipenser baeri* Brandt, the spermatozoon motility decreased from 65% to 40% with increasing water temperature during hormonal treatment, with a considerable depressive effect at 17.5°C when compared to 10°C (Williot *et al.*, 2000)

In Russian sturgeon (*Acipenser gueldenstaedtii* Brandt), the motility and viability ratio of sperm decreased depending on increasing temperature. Motility was seen to progress at the 14°C which is close to incubation degree of sturgeon eggs until 28 minutes and viability ratio recorded as 1-5% at that time. Sperm was kept at +4°C maintained their viability well into the 40-50 minute. After 28th minute, the motility slowed and forward movements were not observed between 33 and 43 minutes but kept shake of tail (Aydin *et al.*, 2012).

The motility duration of the spermatozoa of in paddlefish, *Polyodon spathula*, was up to 4.4 min (Mims 1991) but only 1-5% of spermatozoa are motile at 6 min according to Linhart *et al.*, (1995). In *Acipenser persicus* at temperatures between 15-20 °C the duration of motility was 1.5-5 min while the duration of energetic movement was 5-20 min (Alavi *et al.*, 2004).

Croaker

In *Larimichthys polyactis* the highest and lowest spermatozoa motile parameters were observed at temperatures of 10 and 40°C respectively. After dilution, no significant differences were observed in terms of movable ratio and velocity at 10 and 20°C. However, the duration of motility showed significant differences at 10 and 20°C. Therefore 10°C was the ideal temperature for spermatozoa motility (Le *et al.*, 2011).

Curimbata

The Sperm motility duration in relation to the temperature of the activating solution exhibited a quadratic behavior in curimbata, *Prochilodus lineatus.* A temperature of 17.3°C promoted a sperm motility duration of 21.36s (Romagosa *et al.*, 2010).

The water temperature affected the spermatozoa motility duration in *Rhinelepis aspera*, It showed an inversely proportional linear trend. The high water temperature resulted in lowered duration of sperm motility. In temperatures lower than 5°C longer was the time of spermatozoa activation (Bombardelli *et al.*, 2013).

Solea, Stickleback and Catfishes

In *Solea senegalensis*, the activation solution set at 20ºC showed better total motility throughout time, and improved sperm velocity in the first seconds, compared to 16ºC. Temperature affected the total and progressive motile cells, as well as velocities. In all post-activation times, higher temperatures improved sperm motility significantly (Diogo 2010).

The sperm velocity was significantly influenced by temperatures in *Gasterosteus aculeatus*. An increased sperm swimming speed was recorded at higher temperatures. However, the percentage of motile sperm significantly declined with elevated test temperatures (Mehlis and Bakker 2014).

Coregonus and Bream

Smeshlivaya and Semenchenko (2016) studied the duration of motility in four whitefish species *Coregonus tugun*, Coregonus *peled*, *Coregonus lavaretus pidschian*, *Coregonus nasus*. There was an inversely proportional dependence between water temperature and duration of sperm motility. In temperatures 0.1-5.0°C the average duration of motility was 331 ± 107 s and average duration of forward movement was 149 ± 44s. In temperatures above 7.1°C the average values were 190 ± 47 and 86 ± 15s respectively. The total duration of motility and duration of forward movement in *Coregonus tugun* was 201 and 108 s respectively at 0.7°C. On increasing the temperature to 13.4, these parameters declined 1.2 and 1.1 times.

In Yellowfin bream *Acanthopagrus australis* (Gunther) motility half-life of activated sperm was higher at 4°C than at 20-23°C (5.13:22.8 min) Thorogood and Blackshaw (2008).

Coral Reef and Ornamental Fishes

In coral reef fishes *Zebrasoma scopas* (Acanthuridae), *Abudefduf sexfasciatus*, and *Dascyllus trimaculatus* (Pomacentridae) after sperm activation more than 50% of spermatozoa exhibited progressive movements at 25°C for 3-20, 5-11, and 6-9 min, respectively (Pavlov and Yanova 2006).

In freshwater ornamental fishes, the spermatozoa exhibited longer duration of motility at lower temperatures. In *Rasbora daniconius*, *Puntius filamentosus*, *Parambassis dayi* and *Hyporhamphus xanthopterus*, the spermatozoa showed maximum motility duration at 18ºC.

The duration of motility was 3.4, 94.2, 42.8, 36.2 seconds in *R.daniconius*, *P.filamentosus*, *P. dayi* and *H. xanthopterus* (Joseph *et al.*, 2015).

CONCLUSION

To conclude, sperm motility performance is greatly influenced by temperature. The correlation between sperm motility and temperature is species dependent.

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