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A short review of discovery and development of fish sperm cryopreservation

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ABSTRACT

Global biodiversity, especially fish, has experienced a decline, this occurs as a result of over-exploitation, the presence of introduced fish species and climate change. This condition makes researchers look for solutions to overcome these problems by using cryopreservation techniques. The main purpose of cryopreservation is to store, maintain, and ensure the survival of genetic material, so that using cryopreservation techniques can maintain the viability and function of gamete cells immunologically, biologically and physiologically. The success of the cryopreservation technique has made this technique widely developed in various species of living organism including fish. This article summarizes and reviews the history of the development of cryopreservation of animal species with specific focus on fish.

Introduction

Biodiversity is one of components supporting survival of human life, including for food, development of medicines, science, and even energy. However, global biodiversity experienced a decline in recent years. Presumably is caused by many factors such as specimens' excessive exploitation (legal and illegal), climate change, habitat destruction due to environmental pollution, and the presence of invasive species (Samedi, 2015; Muchlisin *et al.*, 2009). In addition, the uniformity of plant and animal varieties causing genetic erosion resulted in biodiversity crisis (Sutoyo, 2010). This condition attracts experts to find a solution to protect biodiversity and mantain ecological balance trough preservation methods (Hagedorn *et al.*, 2018).

Theoretically, cryopreservation is a process when germplasm such as cells and tissues are preserved in low temperatures (-196°C) (Agarwal, 2011). Phillips and Lardy (1939) were the first to use egg yolks to protect bulls' sperm from coldshock. Egg yolks contain phospholipids and lipoproteins that protect cells from ice crystal formation. Salisbury *et al.* (1941) added sodium citrate in egg yolk media and cooling the samples at temperature of 5°C for 3 days. In 1949, Polge *et al.* (1949) made an important discovery in modern cryobiology that glycerol enables to protect cells at low temperature. The use of glycerol was successful in freezing aves spermatozoa and became a revolution in cattle breeding industry (Pegg, 2002). In 1953, when dairy industry needed a long-term storage for cow spermatozoa, sperm cryopreservation became a very popular topic of study. Since then, cryopreservation methods developed rapidly and successfully in preserving various species including fish.

Research on artificial insemination in poultry was first carried out by Quinn and Burrows (1936) on Black Rosecomb sperm. While cryopreservation of human sperm was first reported by Sherman and Bunge (1953), until 1963, they continued to develop methods of preserving human spermatozoa by following various cryopreservation protocols and freeze-drying techniques. Finally, they found the standard method for human sperm preservation stored in liquid nitrogen at -196°C.

The early development of preservation method in vertebrate such as fish was carried out in a simple way, stored in formalin solution and then transferred to alcohol. This preservation method is commonly

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applied for conventional use and long-term storage. However, this technique reduces the quality of samples for molecular analysis (Hykin and McGuire, 2015). Additionally, preservation at 4-5°C has also been studied yet the quality of the sperm can only last up to 6 days (Eriani *et al.*, 2008).

In the last two decades, there has been a rapid development in the science and technology of specimen preservation, where tissue samples are preserved using ethanol and frozen for DNA (genetic) analysis as phylogenesis purposes. However, specimens in long-term storage experience a decline in quality (Zimmermann *et al.*, 2008; Hagedorn *et al.*, 2018). Therefore, researchers are again exploring preservation method without causing additional damage during storage process.

In actual reference, cryopreservation was first recorded when Lazzaro Spallanzani (1776) attempted to preserve bull sperm using snow (Royere *et al.*, 1996). Further scientific research on sperm cryobiology conducted by Polge *et al.* (1949) found that glycerol could protect poultry sperm during cryopreservation process (Pegg, 2002).

Sperm cryopreservation method was first applied to cattle and human sperm. The development of cattle sperm cryopreservation protocol was started in the 1930s by Phillips (1939), then developed by Bratton *et al.* (1955). Research on artificial insemination of poultry was first carried out by Quinn and Burrows (1936) on Black rosecomb spermatozoa. While cryopreservation of human sperm was first reported by Sherman and Bunge (1953). Until 1963, Sherman and Bunge continued to develop methods of preserving human sperm by seeking various cryopreservation protocols and freeze-drying techniques, resulting in storage technique for human sperm preservation is in liquid nitrogen with a temperature of -196°C.

History and Development of Fish Sperm Cryopreservation

The cryopreservation of fish spermatozoa was first reported by Blaxter (1953) who carried out a cross-breeding and spermatozoa storage of Herring *Clupea harengus* collected in spring and autumn. Blaxter refers to the research of Polge and Rowson (1952) who used carbon dioxide and 15% glycerol at a temperature of -79°C. Since then, many researches and publications have been published regarding cryopreservation of sperm in marine and freshwater fish. According to Hiemstra *et al.* (2005) there have been more than 200 species of freshwater and marine fish whose sperm cryopreservation methods have been recorded until 2005.

Fish cryopreservation has an immense value in protecting populations from extinction due to disease outbreaks, natural disasters, and overexploitation. Cryopreservation of fish spermatozoa also contribute to selective breeding and gene transfer (Agarwal, 2011). In terms of genetic transfer, fish cryopreservation facilitates sperm transport to distant locations. A number of fish sperm cryopreservation protocols have been reported, for instance; common crap *Cyprinus carpio* (Kurokura *et al.*, 1984; Yavas and Bozkurt, 2014), African catfish *Clarias gariepinus* (Horvath and Urbanyi, 2001; Mahfudhah *et al.*, 2020), rainbow trout *Oncorhynchus mykiss* (Cabrita *et al.*, 2001), *Pangasius hypophthalmus* (Kwantong and Bart, 2003), *Mystus nemurus* (Muchlisin *et al.*, 2004), brown trout *Salmo trutta* (Lahnsteiner *et al.*, 2011), and *Siganus guttatus* (Larayanti, 2017).

In Indonesia, there are approximately 9 species of fish with high economic value that has been cryopreserved (Maulida *et al.*, 2020), including *Channa striata* (Mangkunegara *et al.*, 2019), *Chromobotia macracanthus* (Abinawanto *et al.*, 2018), *Tor soro* (Zairin *et al.*, 2005; Alifiani *et al.*, 2020; Fatriani *et al.*, 2020; Harjanti *et al.*, 2020; Laeni *et al.*, 2020; Pamungkas *et al.*, 2020; Putri *et al.*, 2020; Vardini *et al.*, 2020; Wulandari *et al.*, 2020), *Barbonymus gonionotus* (Abinawanto *et al.*, 2013; Abinawanto *et al.*, 2016; Abinawanto and Aisyah, 2018), *Osphronemus goramy* (Abinawanto *et al.*, 2011; Abinawanto *et al.*, 2012a; Abinawanto *et al.*, 2012b; Abinawanto *et al.*, 2015; Abinawanto and Putri, 2017; Abinawanto *et al.*, 2017), *Osteochilus hasseltii* or *Osteochilus vittatus* (Sunarma *et al.*, 2008; Sunarma *et al.*, 2010), *Poropontius tawarensis* (Muthmainnah *et al.*, 2019) and *Rasbora tawarensis* (Muchlisin *et al.*, 2020).

Technique of Fish Sperm Cryopreservation

Based on existing publications, the first Indonesian researcher to conduct research on fish sperm cryopreservation was Muchlisin *et al.* (2004). The study was conducted at Universiti Sains Malaysia on baung fish (*Mystus nemurus*) testing 4 different cryoprotectants, namely DMSO, ethanol, and glycerol. These cryoprotectants were added separately into Ringer's solution as the extender. Results show that the addition of 10% methanol leads to the highest motility of baung spermatozoa (Muchlisin *et al.*, 2004). In 2005, Zairin *et al.* carried out a research on batak fish *T. soro*, and Sunarma *et al.* (2008) on tawes *O. vittatus*. After 16 years of development, only 9 species of native Indonesian fish have been cryopreserved (Maulida *et al.*, 2020). Therefore, the development of fish sperm

cryopreservation in Indonesia is considered relatively slow.

Extender and cryoprotectant play significant role in cryopreservation. The type of extender and cryoprotectant must be adapted to the characteristics of fish sperm cells (Muchlisin, 2005). The extender is a diluent to extend the volume of sperm and increases the fertilization ability of the sperm. Extenders are generally designed to match the physical and chemical composition of sperm cells (Agarwal, 2011). Common extender used for fish cryopreservation are Ringer's solution (Li *et al.*, 1994; Pillai *et al.*, 1994; Muchlisin *et al.*, 2004; Pan *et al.*, 2008; Muchlisin *et al.*, 2018; Muchlisin *et al.*, 2020), NaCl (Gwo, 1993; Glogowski *et al.*, 2002; Maria *et al.*, 2006), artificial seminal plasma (ASP) (Herranz *et al.*, 2019; Le *et al.*, 2011; Lim and Le, 2013), marine fish ringer (MFR) (Kiriyakit *et al.*, 2011; Widyaningsih *et al.*, 2019; Afni *et al.*, 2019), coconut water (Viveiros *et al.*, 2010; Silva *et al.*, 2012; Muchlisin *et al.*, 2010; Muchlisin *et al.*, 2015; Abinawanto and Putri, 2017).

Besides extender, study on cryoprotectant as protective substance for sperm cryopreservation has also been established. In general, there is two types of cryoprotectants, namely; intracellular (permeable) cryoprotectant and extracellular (impermeable) cryoprotectant. An intracellular cryoprotectant is able to penetrate the wall cell and enter inside the cell so that it can provide protection from the inside, while extracellular cryoprotectant cannot penetrate the cell wall so it only provides protection to cells from outside.

Various cryoprotective agents are used to minimize the damage to sperm cells during cryopreservation process. DMSO and glycerol are the most widely used cryoprotectant (Agarwal, 2011) as well as methanol (McOH) (Gazali and Tambing, 2002; Yang *et al.*, 2010; Hagedorn *et al.*, 2012), and lipoproteins derived from milk, egg yolk and vegetable oil (Cerezales *et al.*, 2010; Muchlisin *et al.*, 2015; Yildiz, *et al.*, 2013), DMF (Dimethylformamide) (Varela-Jr. *et al.*, 2012; Perry *et al.*, 2019; Yang *et al.*, 2010), DMA (Dimethylacetamide) (Horvath and Urbanyi, 2001; Baulny *et al.*, 1999; McNiven, 1993) methylglycol (Perry *et al.*, 2019; Viveiros *et al.*, 2009; Maria *et al.*, 2006).

Universal protocols differ from one species to another. Therefore, protocol optimization is needed for each individual species although some general rules are applied for each fish species (Agarwal, 2011). Cryopreservation protocols should be adapted to the type of fish or their habitat, such as the snow trout (*S. richardsonil*) which is used as a model for cryopreservation of freshwater fish sperm (Agarwal, 2011), methanol and glucose (Judycka *et al.*, 2015; Ciereszko *et al.*, 2014; Horvarth *et al.*, 2003). A few researchers in Indonesia develop different extenders such as honey (Mangkunegara *et al.*, 2019; Sunarma, *et al.*, 2010; Sulmartiwi, *et al.*, 2011), and egg yolk (Muchlisin *et al.*, 2015) as extracellular cryoprotectant. Honey are composed of fructose and glucose which are believed to be able to induce early motility and increase sperm fertilization (Muchlisin, 2005).

As technology and science have been advanced, current cryopreservation methods offer antioxidants to protect sperm cells during the cryopreservation process. Chemically, antioxidant compounds are electron-giving compounds (electron donors). Biologically, the notion of antioxidants is a compound reducing the negative impact of oxidants (Winarsi, 2007). Antioxidants are active to protect biological systems due to adverse reaction by reducing, extinguishing or suppressing free radical reactions (Eriani *et al.*, 2018). Some of antioxidants have been tested in fish sperm cryopreservation such as glutathione in *P. tawarensis* (Muthmainnah *et al.*, 2019), superoxide dismutase in brown trout *Salmo trutta* (Lahnsteiner *et al.*, 2011), Uric acid, ascorbic acid, α- tocopherol, methionine in Rainbow trout *Oncorhynchus mykiss* (Kutluyer *et al.*, 2014).

Conclusion

Cryopreservation techniques were first introduced to poultry and cattle. On fish spermatozoa, cryopreservation was first reported by Blaxter (1953) on *Herring Clupea harengus*. In its development, studies on sperm cryopreservation develop to the addition of cryoprotectants and antioxidants. Approximately 200 fish species have been studied for cryopreservation techniques including 9 species from Indonesia.

References

Abianawanto, A., A.I.A. Pratiwi, R. Lestari. 2017. Sperm motility ofgiant gourami (*Osphronemus goramy*, Lacepede, 1801) at several concentrations of honey combined with DMSO after short-term storage. AACL Bioflux, 10 (2): 156-163.

Abinawanto, A., A. Aisyah. 2018. The effect of glycerol on sperm quality of *Barbonymus goniotus* (Bleeker, 1850) postcryopreservation. AIP Conf. Proceeding, 2023 (1).

Abinawanto, A., P.E. Putri. 2017. Goramy spermatozoa quality after subzerofreezing: The roleof coconut wateras the cryoprotectant.Journal of Cell Biology and Development, 1(1):1-5.

Abinawanto, A., I. Anindita, R. Lestari. 2012a. Cryopreservation of spermatozoa of *Osphronemus goramy* fish using skim milk.International Journal of Engineering and Innovation Technology,2(5): 62-64.

Abinawanto, A., M.D. Bayu, R. Lestari, A. Sonarman. 2011. Peranandimetil sulfoksida sebagai krioprotektan dalam mempertahankan kualitas spermatozoa ikan gurami, *Osphronemus goramy* Lacepede, 1801, dua puluh empat jam pascakriopreservasi. Biota, 16 (1):10−15.

Abinawanto, A., N. Fitrianingrum, R. Lestari, A. Sudaryono, R. Rostika, Y. Fujaya. 2015. The intracellular cryoprotectant effects inpreserving goramy spermatozoa after two days sub-zerofreezing. Aquacultura Indonesiana, 16 (1): 16-21.

Abinawanto, A., N. Khairani, R. Lestari. 2012b. The effect if sucrose onsperm quality of *Osphronemus goramy* two days post-crypreservation. International Journal of Aquatic Science, 3 (1): 23-28.

Abinawanto, A., S. Rahayu, R. Lestari. 2013. Cryopreservation of Javabarb (*Barbonymus gonionotus*) using egg yolk as a cryoprotectant. Global Veterinaria, 10: 318-321.

Abinawanto, A., R. Wulandari, Z.A. Muchlisin. 2018. Effect of egg yolk on the spermatozoa quality of the botia *Chromobotia macracanthus* (Bleeker, 1852) (Cyprinidae) after short-term cryopreservation. AACL Bioflux, 11 (6): 1737-1744.

Abinawanto, A., Zuraida, R. Lestari. 2016. The effect of skim milkcombined with 5% of methanol on motiliy, viability, and abnormality of Java barb, *Barbonymus gonionotus* spermatozoa after 24 hours freezing. AACL Bioflux, 9 (2): 326-333.

Afni, R.T., A. Abinawanto, R. Lestari, A. Bowolaksono, N.G. Zavitri. 2019. Spermatozoa motility of giant grouper (*Epinephelus lanceolatus*) 48 hours: The roleof soybean milk as a cryoprotectant. AIP Conf. Proceeding 2168, 020092.

Agarwal, N.K. 2011. Cryopreservation of semen fish. Himalayan Aquatic Biodiversity Conservation dan New Tools in Biotechnology, 104-127.

Alifiani, D.P., A. Abinawanto, J. Subagja, A.H. Kristanto. 2020. Effectof date palm (*Phoenix dactylifera* l.) on spermatozoa viability ofkancra fish (*Tor soro* Valenciennes 1842) 48 hours postcryopreservation. Proceeding of 2nd International Conference on Fisheries and Marine Science, 2020. IOP Conf. Series: Earth andEnvironmental Science, 012067-1-012067-5.

Baulny, B.O., C. Labbe, G. Maisse. 1999. Membrane integrity, mitochondrial activity, ATP content, and motility of the European catfish (*Silurus glanis*) testicular spermatozoa after freezing with different cryoprotectants. Cryobiology, 39 (2): 177-184.

Blaxter, J.H.S. 1953. Sperm storage and cross-fertilization of spring and autumn spawning herring. Nature, 172: 1189-1190

Bratton, R.W., R.H. Foote, J.C. Cruthers. 1955. Preliminary fertility results with frozen bovine spermatozoa. Journal of Dairy Science, 38: 40- 46.

Cabrita, E., L. Anel, M.P. Herraéz. 2001. Effect of external cryoprotectants as membrane stabilizers on cryopreserved rainbow trout sperm. Journal of Theriogenology, 56 (4): 623-635.

Cerezales, S.P., S.M. Paramo, J. Beirao, M.P. Herraez. 2010. Evaluation of DNA damage as a quality marker for rainbow trout sperm cryopreservation and use of LDL as cryoprotectant. Theriogenology, 74 (2): 282-289.

Ciereszko, A., G.J. Dietrich, J. Nynca, S. Dobosz, T. Zalewski. 2014. Cryopreservation of rainbow trout semen using a glucose-methanol extender. Aquaculture, 420-421: 275-281.

Eriani, K., A. Boediono, I. Djuwita, S.H. Sumarsono, A. Azhar. 2008. Development of dosmetic cat embryo produced by preserved sperms. HAYATI Journal of Bioscience, 15 (4): 155-160.

Eriani, K., A. Azhar, B. Rosadi, M. Rizal, A. Boediono. 2018. Quality enhancement of Aceh swamp buffalo (*Bubalus bubalis*) frozen semen bysupplementing β-Carotene. Tropical Animal Science Journal, 41 (1): 1-7.

Fatriani, R., A. Abinawanto, O.Z. Arifin, A.H. Kristanto. 2020. Sperm motility of kancra fish (*Tor soro*, Valenciennes 1842) after frozen: the effect of soybean milk as a natural cryoprotectant. Proceeding of 2nd International Conference on Fisheries and Marine Science, 2020. IOP Conf. Series: Earth and Environmental Science, 012066-1-012066-5.

Gazali, M., S.N. Tambing. 2002. Kriopreservasi sel sperma. Hayati, 9: 27-32.

Glogowski, J., R. Kolman, M. Szczepkowski, A. Horvath, B. Urbanyi, P. Sieczynski, A. Rzemieniecki, J. Domagala, W. Demianowicz, R. Kowalski, A. Ciereszko. 2002. Fertilization rate of Siberian sturgeon (*Acipenser baeri*, Brandt) milt cryopreserved with methanol. Aquaculture, 211: 367-373.

Gwo, J.C. 1993. Cropreservation of black gouper (*Epinephelus malabaricus*) spermatozoa. Theriogenology, 39: 1331-1242.

Hagedorn, M., M. Mc.Carthy, V.L. Carter, S.A. Meyers. 2012. Oxidative stress in Zebrafish (*Danio rerio*) Sperm. Journal of Plos One, 7 (6): 1-11.

Hagedorn, M.M.., J.P. Daly, V.L. Carter, K.S. Cole, Z. Jaafar, C.V.A. Lager, L.R. Parenti. 2018. Cryopreservation of fish spermatogonial cells: the future of natural history collections. Nature, 8: 6149.

Harjanti, E R., A. Abinawanto, O.Z. Arifin, A.H. Kristanto. 2020. The fertilization of *Tor soro* fish (Valenciennes, 1842) using post cryopreservation sperm: the effect of skim milk as acryoprotectant. Proceeding of 2nd International Conference onFisheries and Marine Science, 2020. IOP Conf. Series: Earth andEnvironmental Science, pp. 012061-1-012061-6.

Herranz-Jusdado, J.G., V. Gallego, M. Morini, C. Rozenfeld, L. Perez, T. Muller, A. Horvarth, H. Ohta, J.F. Asturiano. 2019. Sel sperm cryopreservation: an overview. Theriogenology, 133: 210-215.

Hiemstra, S.J., T. Van der Lende, dan H. Woelders. 2005. The potential of cryopreservation and reproductive technologies for animal genetic resources conservation strategies. Proc. Symp. role of biotechnology, Villa Gualino, Turin, Italy (5-7 March): 25-35.

Horvarth, A., E. Miskolczi, B. Urbanyi. 2003. Cryopreservation of common carp sperm. Aquatic Living Resources, 16: 457-460.

Horvath, A., B. Urbanyi. 2001. The effect of cryoprotectan on the mortility and fertilizing capacity of cryopreserved African catfish *Clarias gariepinus* (Burchell 1822) sperm. Aquaculture Research, 31: 317-324.

Hykin, S.M., K. Bi,dan J.A. McGuire. 2015. Fixing formalin: a method to recover genomic-scale DNA sequence data from formalin-fixed museum specimens using high-throughput sequencing. Journal Plos One: 1-16.

Judycka, S., M. Szczepkowski, A. Ciereszko, G.J. Dietrich. 2015. New extender for cryopreservation of Siberian sturgeon (*Acipenser baerii*) semen. Cryobiology, 70: 184-189.

Kiriyakit, A., W.G. Gallardo, A.M. Bart. 2011. Successful hybridization of groupers (*Epinephelus coioides* x *Epinephelus lanceolatus*) using cryopreserved sperm. Aquaculture, 320: 106-112.

Kurokura, H., R. Hirano, M. Tomita, M. Iwahashi. 1984. Cryopreservation of carp sperm. Aquaculture, 37: 267-273.

Kutluyer, F., M. Kayim, F. Öğretmen, S. Büyükleblebici, P.B. Tuncer. 2014. Cryopreservation of rainbow trout *Oncorhynchus mykiss* spermatozoa: effects of extender supplemented with different antioxidants on sperm motility, velocity and fertility. Cryobiology, 69: 462–466.

Kwantong, S., A.N. Bart. 2003. Effect of cryoprotectants, extender, and freezing rates on the fertilization rate of frozen striped catfish *Pangasius hypophthalmus* (sauvage) sperm. Aquaculture Research, 34: 887-893.

Laeni, M., A. Abinawanto, J. Subagja, A.H. Kristanto, 2020. The effect ofvarious concentration of quail egg yolk on spermatozoa motility ofkancra fish (*Tor soro* Valenciennes, 1842) post cryopreservation. Proceeding of 2nd International Conference on Fisheries and Marine Science, 2020. IOP Conf. Series: Earth and Environmental Science, 012060-1-012060-5.

Lahnsteiner, F., N. Mansour, K. Plaetzer. 2011. Antioxidant systems of brown trout (*Salmo trutta* f. fario) semen. Animal Reproduction Science, 119 (3-4): 314-321.

Larayanti, 2017. Kriopreservasi semen ikan baronang *Siganus guttatus* menggunakan beberapa jenis larutan extender. Tesis, Universitas Hasanuddin, Makasar.

Le, M.H., H.K. Lim, B.H. Min, M.W. Park. 2011. Semen cryopreservation of yellow croaker *Larimichthys polyactis*. Review in Fish Biolology and Fisheries, 21: 789-797.

Li, J., Y. Li, X.X. Zhao, S.M. Zhang, Y.H. Zhang, K.B. Jiang, Z.X. Yang. 1994. Sperm cells as vectors for introducing foreign DNA into eggs of Tilapoa. Biotechnology, 4 (3), 20–22.

Lim, H.K., M.H. Le. 2013. Evaluation of extenders and cryoprotectants on motility and morphologyof longtooth grouper (*Epinephelus bruneus*) sperm. Theriogenology, 79: 867-871.

Mahfudhah, R., K. Eriani, Z.A. Muchlisin. 2020. The effect of glutathione on the quality of Aceh local catfish (*Clarias gariepinus*)

spermatozoa after cryopreservation. Journal of Biology and Biology Education, 12 (1): 125-131.

Mangkunegara, A.A., S.H. Dwinanti, M. Syaifudin. 2019. Pemanfaatan madu sebagai bahan ekstender untuk kriopreservasi sperma ikan gabus (*Channa striata*). Jurnal Akuakultur Rawa Indonesia, 7 (2): 123-134.

Maria, A.N., A.T.M. Viveiros, R.T.F. Freitas, A.V. Oliveira. 2006. Extenders and cryoprotectants for cooling and freezing of piracanjuba (*Brycon orbignyanuus*) semen, an endangered Brazilian teleost fish. Aquaculture, 260: 298-306.

Maulida, S., F.M. Nur, K. Eriani, Z.A. Muchlisin. 2020. Tinjauan kepustakaan tentang pengembangan kriopreservasi sperma ikan asli Indonesia. Depik Jurnal Ilmu-Ilmu Perairan, Perikanan dan Pesisir, 9 (2): 141-150.

McNiven, M.A., R.K. Gallant, G.F. Richardson. 1993. Dimethyl-acetamide as a cryoprotectant for rainbow trout spermatozoa. Theriogenology, 40 (5): 943-948.

Muchlisin, Z.A., R. Hashim, A.S.C. Chong. 2004. Preliminary study on the cryopreservation of tropical bagrid catfish (*Mystus nemurus*) spermatozoa; the effect of extender and cryoprotectant on the motility after short-term storage. Theriogenology, 62 (1-2): 25-34.

Muchlisin, Z.A. 2005. Current Status of Extenders and Cryoprotectants on Fish Spermatozoa Cryopreservation. Biodiversitas, 6 (1): 66-69.

Muchlisin, Z.A., M.N. Siti Azizah, E. Rudi, N. Fadli. 2009. Danau Laut Tawar dan beberapa permasalahannya. Dipresentasikan pada Workshop Selamatkan Danau Laut Tawar, Takengon 21-22 November 2009.

Muchlisin Z.A., N. Nadiya, W.N. Nadiah, M. Musman, M.N. Siti-Azizah. 2010. Preliminary study on the natural extenders for artificial breeding of African catfish *Clarias gariepinus* (Burchell, 1822). AACL Bioflux, 3 (2): 119- 124.

Muchlisin, Z.A., W.N. Nadiah, N. Nadiya, N. Fadli, A. Hendri, M. Khalil, M.N. Siti-Azizah. 2015. Exploration of natural cryoprotectants for cryopreservation of African catfish, *Clarias gariepinus*, Burchell 1822 (Pisces: Clariidae) spermatozoa. Chezch Journal of Animal Sciences, 60 (1): 10-15.

Muchlisin, Z.A., I. Hasri, A.S. Batubara. 2018. A mini review on endemic and threatened fish *Rasbora tawarensis* in Lake Laut Tawar, Indonesia. IOP Conference Series: Earth and Environmental Science, 2016: 012045.

Muchlisin, Z. A., F.A. Dhea, K. Eriani, P.I.Sarah, I. Hasri, A.S. Batubara, Mustaqim. 2020. Effect of dimethyl sulfoxide (DMSO) and egg yolk on sperm motility, fertility and hatching rate of depik *Rasbora tawarensis* (Pisces: Cyprinidae) eggs after short-term cryopreservation. Aquaculture Research, 51(4): 1700-1705.

Muthmainnah, C.R., K. Eriani, I. Hasri, N. Fadli, A.A. Muhammadar, Z.A. Muchlisin. 2019. Kriopresevasi sperma ikan kawan *Poropontius tawarensis* menggunakan dimetil sulfoxida (DMSO). Depik, 8 (3): 158-166.

Pamungkas, M.A.B., A. Abinawanto, O.Z. Arifin, A.H. Kristanto. 2020. The spermatozoa viability of kancra fish (*Tor soro*, Valenciennes 1842) 48-hour after freezing: effect of brown sugar as naturalcryoprotectant. Proceeding of 2nd International Conference on Fisheries and Marine Science, 2020. IOP Conf. Series: Earth and Environmental Science, 012063-1-012063-5.

Pan, J., S. Ding, J. Ge, W. Yan, C. Hao, J. Chen, Y. Huang. 2008. Development of cryopreservation for maintaining yellow catfish *Pelteobagrus fulvidraco* sperm. Auaqulture, 279: 173-176.

Pegg, D.E. 2002. The History and principles of cryopreservation. Seminars in Reproductive Medicine, 20 (1): 5-13.

Perry, C. T., C.D. Corcini, A.N. Anciuti, M.V. Otte, S.L. Soares, J.RE. Garcia, J.R.E. Muelbet, S.V. Junior. 2019. Amides as cryoprotectants for the freezing of *Brycon orbignyanus* sperm. Aquaculture, 508: 90-97.

Phillips, P.H., Lardy, H.A. 1939. Preservation of spermatozoa. Journal of Animal Science, 1939(1): 219-221.

Pillai, M.C., R. Yanagimachi, G.N. Cherr. 1994. In vivo and in vitro initiation of sperm motility using fresh and cryopreserved gametes from the pacific herring, *Clupea pallasi*. The Journal of Experimental Zoology, 269: 62-68.

Polge, C., A.U. Smith, A.S. Parkes. 1949. Revival of spermatozoa after vitrification and dehydration at low temperatures. Nature, 164: 666.

Polge, C., Rawson, L.E.A. 1952. Results with bull semen of spermatozoa after vitrification and dehydration at low temperatures. Veterinary Record, 64: 851.

Putri, B.S.D., A. Abinawanto, O.Z. Arifin, A.H. Kristanto. 2020. Honey effect on sperm motility of kancra fish (*Tor soro* Valenciennes, 1842) after 48 hours freezing. Proceeding of 2nd International Conference on Fisheries and Marine Science. IOP Conf. Series: Earth and Environmental Science, 012062.

Quinn, J.P., W.H. Burrows. 1936. Artificial Insemination in Flows. The Journal of Heredity, 31-37.

Royere, D., C. Barthelemy, S. Hamamah, J. Lansac. 1996. Cryopreservation of spermatozoa: a 1996 review. Hum Reprod. Update, 2: 553-559.

Salisvury, G.W., Fuller, H.K., Willet, E.L. 1941. Preservation of bovine spermatozoa in yolk-citrate diluent and field results from its use. Journal of Dairy Science, 24 (11): 905-910.

Samedi. 2015. Konservasi keanekaragaman hayati di Indonesia: Rekomendasi Perbaikan Undang-undang Konservasi. Jurnal Hukum Lingkungan Indonesia, 2 (2): 1-28.

Sherman, J.K., R.G. Bunge. 1953. Fertilizing capacity of frozen human spermatozoa. Nature, 172: 767-768.

Silva, M.A., G.C.X. Peixoto, G.L. Lima, J.A.B. Bezerra, L.B. Campos, A.L.C. Paiva, V.V. Paula, A.R. Silva. 2012. Cryopreservation of collared peccaries (*Tayassu tajacu*) semen using a powdered coconut water (ACP-116c) based extender plus various concentrations of egg yolk and glycerol. Theriogenology, 78: 605-611.

Sulmartiwi, L., E. Alnurrohmah, A.S. Mubarak. 2011. Pengaruh konsentrasi air kelapa muda dan madu dalam NaCl fisiologis terhadap motilitas dan lama hidup spermatozoa ikan patin (*Pangasius pangasius*). Jurnal Ilmiah Perikanan dan Kelautan, 3 (1): 67-72.

Sunarma, A., D.W. Budihastuti, Y. Sistina. 2010. Penggunaan ekstender madu yang dikombinasikan dengan krioprotektan berbeda pada pengawetan sperma ikan nilem (Indonesian Sharkminnow, *Osteochilus hasseltii,* 1842). Jurnal Omni-Akuatika, 9 (11): 51-55.

Sunarma, A., D.W. BudiHastuti, D.M. Saleh, Y. Sistina. 2008. Kombinasi efektif ekstender dan krioprotektan pada kriopreservasi sperma ikan nilem (*Osteochilus hasseltii* Valenciennes, 1842). Jurnal Perikanan, 10 (1): 76-84.

Sutoyo. 2010. Keanekaragaman hayati Indonesia. Buana Sains, 10 (2): 101-106.

Vardini, N., A. Abinawanto, J. Subagja, A.H. Kristanto. 2020. The spermatozoa motility of kancra fish (*Tor soro* Valenciennes, 1842) after the frozen process: the application of egg yolk as a cryoprotectant. Proceeding of 2nd International Conference on Fisheries and Marine Science, 2020. IOP Conf. Series: Earth and Environmental Science, 012065-1-012065-5.

Varela-Jr., A.S., S.D. Corcini, S.M.M. Gheller, R.D. Jardim, T. Lucia-Jr., Streit-Jr., M.R.C. Figuereido. 2012. Use of amides as cryoprotectants in extenders for frozen sperm of tambaqui, *Colossoma macropomum*. Theriogenology, 78 (2): 244-251.

Viveiros, A.T.M., A.F. Nascimento, L.H. Orfao, Z.A. Isau. 2010. Motility and fertility of the subtropical freshwater fish streaked prochilod (*Prochilodus lineatus*) sperm cryopreserved in powdered coconut water. Theriogenology, 74: 551-556.

Viveiros, A.T.M., L.H. Orfao, A.N. Maria, B. Allaman. 2009. A simple, inexpensive and successful freezing method for curimba *Prochilodus lineatus* (Characiformes) semen. Animal Reproduction Scioence, 112 (3-4): 293-400.

Widyaningsih, W.A., A. Abinawanto, R. Lestari, A. Bowolaksono, N.G. Zavitri. 2019. Effect of various concentrations of palmdate (*Phoenix dactylifera* L.) on spermatozoamotility of giant grouper (*Epinephelus lanceolatus*). AIP Conference Proceedings 2168, 020093.

Winarsi, H. 2007. Antioksidan alami dan radikal bebas. Kanisius, Yogyakarta.

Wulandari, P.D., A. Abinawanto, A., J. Subagja, A.H. Kristanto. 2020. Viability of Tor fish spermatozoa (*Tor soro*, Valenciennes 1842) 48

hours cryopreservation: the effects of duck egg yolk as a natural cryoprotectant. Proceeding of 2nd International Conference on Fisheries and Marine Science. IOP Conf. Series: Earth and Environmental Science, 012102-1-012102-5.

Yang, H., M. Norris, R. Winn, T.R. Tiersch. 2010. Evaluation of cryoprotectant and cooling rate for sperm cryopreservation in the euryhaline fish medaka *Oryzias latipes*. Cryobiology, 61 (2): 211-219.

Yavas, I., Y. Bozkurt. 2014. Cryopreservation of scaly carp (*Cyprinus caprio*) sperm: effect of different cryoprotectant concentrations on post-thraw motility, fertilization and hatching success of embryos. Aquaculture International., 22: 141-148.

Yildiz, C., Y. Bozkurt, I. Yavas. 2013. An evaluation of soybean lecithin as an alternative to avian egg yolk in the cryopreservation of fish sperm. Cryobiology, 67 (1): 91-94.

Zairin, M.S. I. Handayani, Supriatna. 2005. Kualitas sperma ikan batak (*Tor soro*) hasil kriopreservasi semen menggunakan dimetil sulfoksida (DMSO) dan gliserol 5, 10 dan 15%. Jurnal Akuakultur Indonesia, 4(2): 145–15.

Zimmermann, J. M. Hajibabaei, D.C. Blackcurn, J. Hanken, E. Cantin, J. Posfai, dan T.C. Evans-Jr,. 2008. DNA Damage in Preserved Specimens and Tissue Samples: a Molecular Assessment. Frontiers in Zoology, 5 (18): 1-13.

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