Understanding Antimicrobial Resistance and Biosecurity in Aquaculture

FAO candidate Reference Centers on AMR and Aquaculture Biosecurity

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Status and prospects for development and application of fish vaccines

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CONTENT

PART

1

Why fish needs vaccines?

1. Production of major species in the finfish aquaculture of world

	2010	2012	2014	2016	2018	2018 share
	(thousand tonnes)					(percentage)
Finfish						
Grass carp, *Ctenopharyngodon idellus*	4 213.1	4 590.9	5 039.8	5 444.5	5 704.0	10.5
Silver carp, *Hypophthalmichthys molitrix*	3 972.0	3 863.8	4 575.4	4 717.0	4 788.5	8.8
Nile tilapia, *Oreochromis niloticus*	2 657.7	3 342.2	3 758.4	4 165.0	4 525.4	8.3
Common carp, *Cyprinus carpio*	3 331.0	3 493.9	3 866.3	4 054.7	4 189.5	7.7
Bighead carp, *Hypophthalmichthys nobilis*	2 496.9	2 646.4	2 957.6	3 161.5	3 143.7	5.8
Catla, *Catla catla*	2 526.4	2 260.6	2 269.4	2 509.4	3 041.3	5.6
Carassius spp.	2 137.8	2 232.6	2 511.9	2 726.7	2 772.3	5.1
Freshwater fishes nei,[1] Osteichthyes	1 355.9	1 857.4	1 983.5	2 582.0	2 545.1	4.7
Atlantic salmon, *Salmo salar*	1 437.1	2 074.4	2 348.1	2 247.3	2 435.9	4.5
Striped catfish, *Pangasianodon hypophthalmus*	1 749.4	1 985.4	2 036.8	2 191.7	2 359.5	4.3
Roho labeo, *Labeo rohita*	1 133.2	1 566.0	1 670.2	1 842.7	2 016.8	3.7
Milkfish, *Chanos chanos*	808.6	943.3	1 041.4	1 194.8	1 327.2	2.4
Torpedo-shaped catfishes nei, *Clarias* spp.	343.3	540.8	867.0	961.7	1 245.3	2.3
Tilapias nei, *Oreochromis* (=Tilapia) spp.	472.5	693.4	960.8	972.6	1 030.0	1.9
Rainbow trout, *Oncorhynchus mykiss*	752.4	882.1	794.9	832.1	848.1	1.6
Wuchang bream, *Megalobrama amblycephala*	629.2	642.8	710.3	858.4	783.5	1.4
Marine fishes nei, Osteichthyes	467.7	567.2	661.0	688.3	767.5	1.4
Black carp, *Mylopharyngodon piceus*	409.5	450.9	505.7	680.0	691.5	1.3
Cyprinids nei, Cyprinidae	639.8	601.1	628.0	596.1	654.1	1.2
Yellow catfish, *Pelteobagrus fulvidraco*	177.8	233.7	302.7	434.4	509.6	0.9
Other finfishes	6 033.9	6 869.3	7 730.0	8 217.1	8 900.2	16.4
Finfish total	**37 745.1**	**42 338.2**	**47 219.1**	**51 078.0**	**54 279.0**	**100**

(The State of World Fisheries and Aquaculture 2020)

- In 2018, aquaculture fish production was dominated by finfish (54.3 million tonnes – 47 million tonnes from inland aquaculture and 7.3 million tonnes from marine and coastal aquaculture. (FAO, 2020)
- In 2018, aquaculture fish production was 27 million tonnes, occupied 49.7% of world aquaculture fish (China Fishery Statistical yearbook, 2019)

2. Production decline could be caused by some factors

Dead sardines on a beach in Mulegé.

Thousands of tonnes of sardines and other marine life wash up on Baja coast

Above normal ocean temperatures as high as 30 C were responsible, said a fisheries official

Published on Wednesday, July 14, 2021

13:30
10 Mayıs 2021

Dicle Nehri'nde Binlerce Ölü Balık Kıyıya Vurdu

Diyarbakır'ın Çınar ilçesinde Dicle Nehri kenarında binlerce ölü balık kıyıya vurdu. Bu durum vatandaşlar arasında paniğe neden oldu.

Bacterium Probable Cause of Local Massive Fish Kills

April 9, 2021

4539

Thousands of dead menhaden have been washing up on the banks of the Navesink River lately. The kills are most likely caused by a bacterial infection affecting the fishes' nervous system. Courtesy Rick Swanson

....

Disease outbreak

Environmental pollution

Climate change

Massive death of fish

3. Main fish diseases caused by pathogens

According to the China Fisheries Statistics Yearbook, disease outbreaks caused a direct production loss to Chinese aquaculture of 205 000 tonnes, worth USD 401 million (CNY 2.6 billion) (FA0, 2020) .

Virus

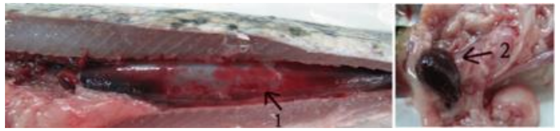

GCRV


SVCV


ISKNV

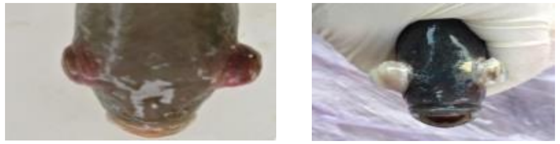

KHV


TiLV


HSRV

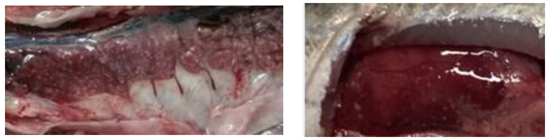
Bacteria


Aeromonas spp


Streptococcus agalactiae


F. columnare

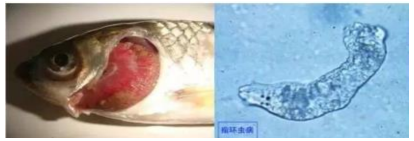

P. aeruginosa


Aeromonas schubertii

Parasite


Ichthyophthirius multifiliis


Anchor worm


Dactylogyrus


Gyrodactylus

Fungus


Saprolegnia


epizootic ulcerative syndrome, EUS

Major pathogens of farmed fish in global aquaculture

Disease	Pathogen	Major Fish Host
Bacterial diseases		
Bacterial kidney disease (BKD)	*Renibacterium salmoninarum*	Salmonids
Edwardsiellosis/Redpest	*Edwardsiella tarda*	Salmon, catfish, carps, turbot, flounder, eel, tilapia
Edwardsiellosis/Enteric septicemia	*Edwardsiella ictaluri*	Channel catfish, freshwater catfish, striped catfish, brown bullhead, *Donio* spp.
Flavobacteriosis/Columnaris	*Flavobacterium columnare*, *Flavobacterium maritimus*	Cyprinids, salmonids, catfish carp, trout, perch, tilapia
Furunculosis	*Aeromonas salmonicida*	Salmons, trout, flounder, turbot, carp, tilapia, sole
Lactococcosis	*Lactococcus garvieae*	Salmonids, seabream, seabass, *Seriola* spp.
Motile Aeromonas Septicaemia	*Aeromonas hydrophila*, *Aeromonas salmonicida*	Salmonids, bass, carp, trout, eel, sturgeon, tilapia
Pasteurellosis	*Photobacterium. damselae* spp. *piscicida*	Seabream, seabass, ayu, yellowtail, carp, sturgeon, hybrid striped bass, tuna, cobia, snakehead
Piscirickettsiosis/Rickettsial septicemia	*Piscirickettsia salmonis*	Salmonids, trout, seabass, tilapia
Streptococcosis	*Streptococcus agalactiae*, *Streptococcus iniae*, *Streptococcus dysgalactiae*, *Streptococcus parauberis*, *Streptococcus phocae*	Grouper, salmonids, turbot, flounder, sturgeon, amberjack, yellow tail, red porgy, barramundi, rabbitfish, seabass, seabream, hybrid striped bass, catfish, mullet, pomfret, tilapia, koi, carp
Vibriosis	*Vibrio alginolyticus*, *Vibrio parahaemolyticus*, *Vibrio vulnificus*, *Vibrio anguillarum*	Most marine fish, salmonids, groupers, cods, red seabream, gilt-head sea bream, Japanese flounder, summer flounder, amberjack, halibut, yellowtail, seabass, seriolla, milkfish, horse mackerel, cobria, sole, eel, tilapia
Yersiniosis/Enteric redmouth	*Yersinia ruckeri*	Salmonids, trout, eel, minnows, tilapia
Wound Disease	*Moritella viscosa*	Salmonids
Tenacibaculosis	*Tenacibaculum maritimum*	Turbot

Modified from doi: 10.14202/vetworld.2019.1806-1815

Disease	Pathogen	Major Fish Host	OIE listed (2020)
		Viral Diseases	
Infectious hematopoietic necrosis	IHNV	Salmonids,Trout,Cod,Pike,Sturgeon	Yes
Infectious pancreatic necrosis	IPNV	Salmonids, sea bass, sea bream, turbot, Pacific cod,Carp,Goldfish	No
Infectious salmon anemia	ISAV	Atlantic salmon	Yes
Pancreatic disease virus	SAV	Salmonids	Yes
Spring viremia of carp virus	SVCV	Common carp, Grass carp, Bighead carp, Silver carp,Goldfish	Yes
Red seabream iridoviral disease	RSIV	Red sea bream, black porgy, amberjack	Yes
Epizootic hematopoietic necrosis	EHNV	Redfin perch, rainbow trout,macquarie perch, silver perch	Yes
Koi herpesvirus disease	KHV,CyHV-3	Koi,Common Carp	Yes
Infectious spleen and kidney necrosis	ISKNV	Mandarin fish,Asian seabass, grouper, Japanese yellowtail	No
Grass Carp Hemorrhage	GCRV	Grass carp,Black carp	No
		Parasitic diseases	
Mastigophora	*Amyloodinium ocellatum;Trypanosoma*		
Sporozoan	*Myxosporidia*	freshwater fish and marine fish	No
Infusorian	*Ichthyophthirius multifiliis;Cryptocaryon irritans*	freshwater fish and marine fish	No
Monogenean	*Dactylogyrus sp.;Benedenia sp.; Gyrodactylus salaris*	freshwater fish and marine fish	Yes(*G. Salaris*)
Digenea	*Sanguinicola spp.*	freshwater fish and marine fish	No
		Fungal diseases	
Saprolegniasis	*S. monoica;S. parasitica;S. diclina*	All freshwater fish species	No
Branchiomycosis	*B. sanguinis;B. demigrans*	Grass carp,Black carp	No
Aphanomyces	*A. pisiciidia;A. laevis;A. invadans*	Grass carp,goldfish,Sliver carp,Bighead carp	Yes(*A. invadans*)

IHNV: Infectious hematopoietic necrosis virus; IPNV: Infectious pancreatic necrosis virus; ISAV: Infectious salmon anemia virus; SAV:alphavirus alphavirus;SVCV: Spring viremia of carp virus;RSIV: Red sea bream iridovirus;KHV: Koi herpesvirus;EHNV:Epizootic hematopoieticnecrosis virus;CyHV-3:Cyprinid herpesvirus-3; ISKNV: Infectious spleen and kidney necrosis virus;GCRV:Grass carp reovirus

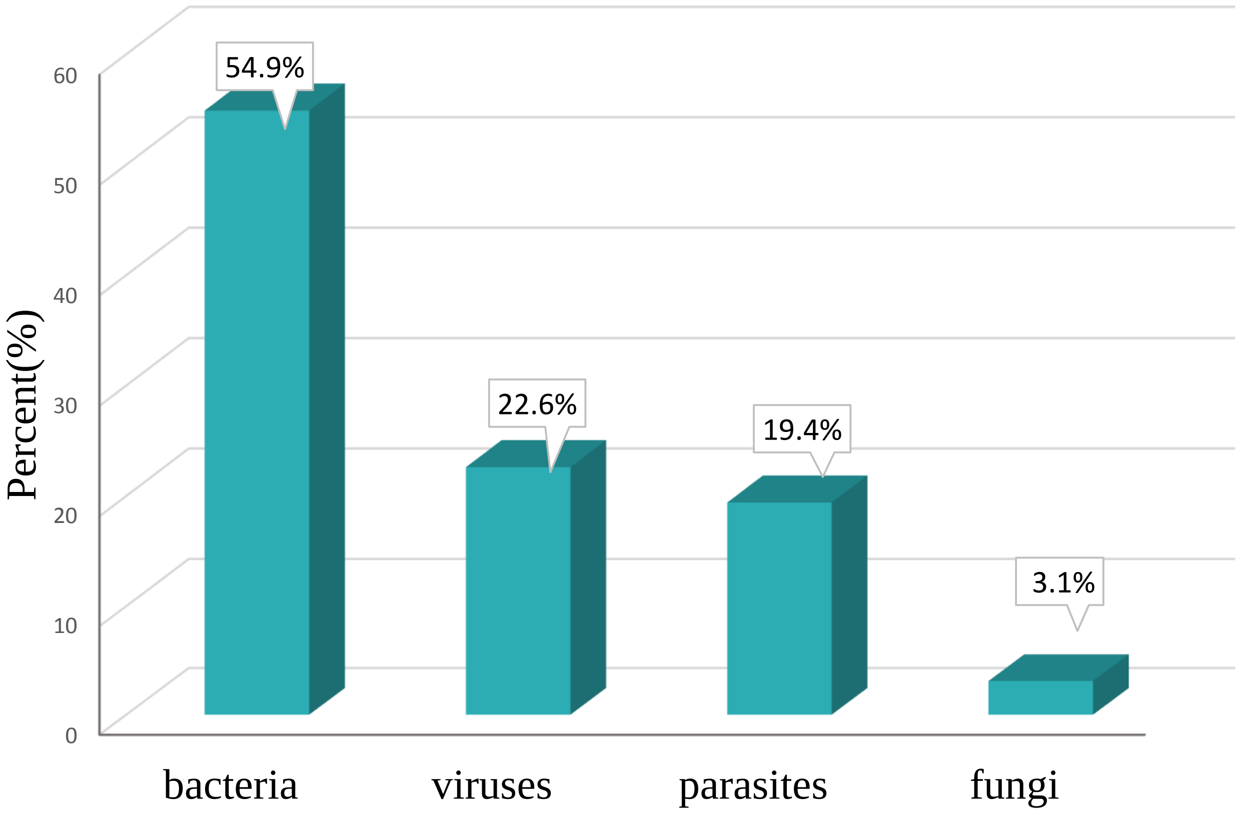


Fig 1. The proportion of various pathogens in global cultured fish

Modified from doi:10.1007/s13337-013-0186-4

The major causative agents of infectious diseases in finfish aquaculture include

- bacteria (54.9 %)
- viruses (22.6 %)
- parasites (19.4 %)
- fungi (3.1 %).

The World Health Organization (WHO) has stated that "Antimicrobials are vital medicines for the treatment of bacterial infections in both human and animals".

4. How to control diseases outbreak and lower antibiotics use

Blocking pathogen

Pathogen surveillance

Quarantine of juveniles

Immune technology

Immunopotentiator

Vaccination

Ecological prevention and control technology

Anti-stress

Environment improvement

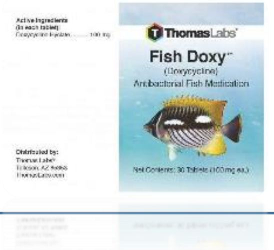
Immunity improvement

Chemicals

Water disinfectant

Antibiotics

Antiscolic



prevention

control

Integrated Control Technology

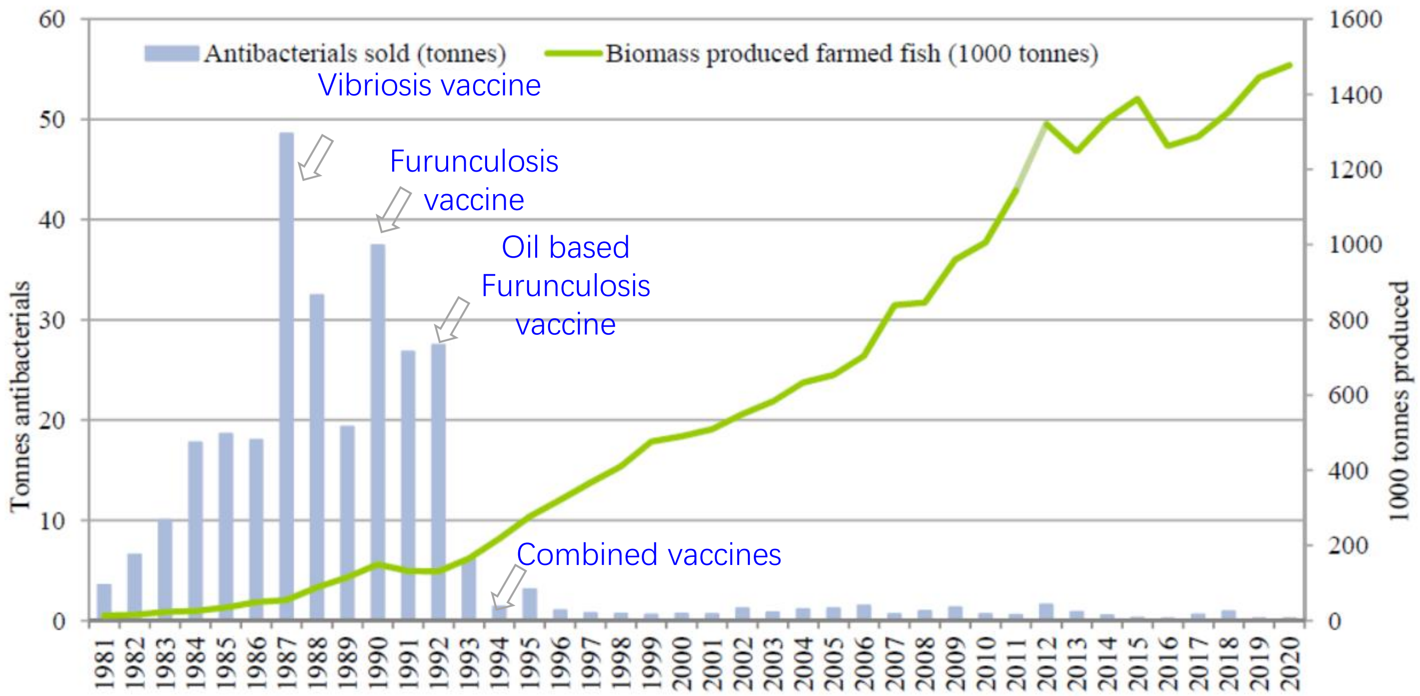
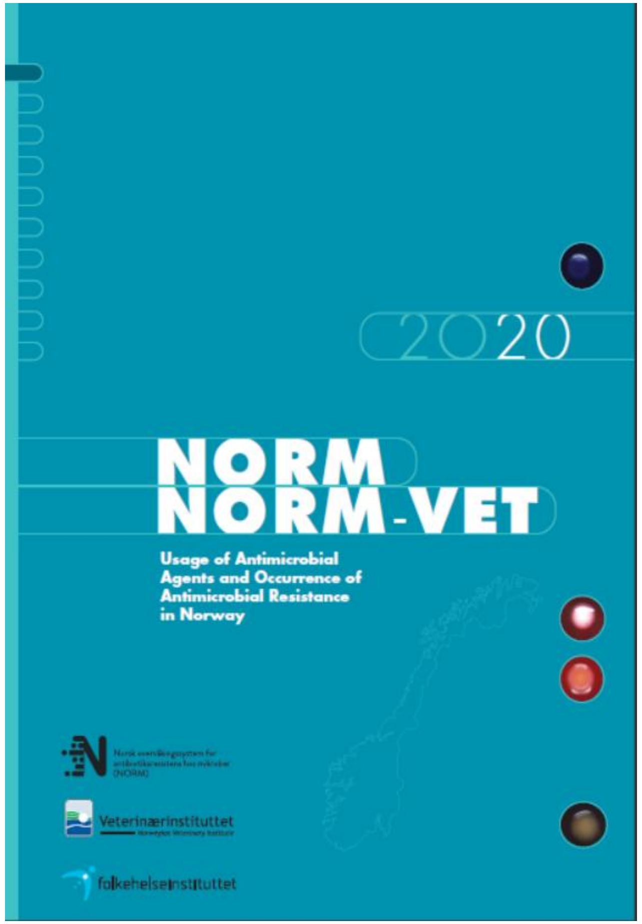


FIGURE 8. Sales, in tonnes of active substance, of antibacterial veterinary medicinal products for therapeutic use in farmed fish (including cleaner fish) in Norway in 1981-2020 versus tonnes produced (slaughtered) farmed fish. For the years 1981-2012 the data represent sales data provided by Norwegian Institute of Public Health; for 2013-2020 data represent prescription data obtained form the Veterinary Prescription Register. Data on slaughtered biomass farmed fish were obtained from Norwegian Directorate of Fisheries (https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/Akvakulturstatistikk-tidsserier).



The significant decrease in the usage of antibacterial agents in Norwegian aquaculture from 1987 is mainly attributed to the introduction of effective vaccines against bacterial diseases in Atlantic salmon and rainbow trout but also prevention of bacterial diseases and their spread.

PART

2

What vaccines can we choose?

1. Development history of aquatic vaccines

1942

Step 01

Research beginning

Successfully prepared vaccine against *Aeromonas salmonicida*

1976

Step 02

Production beginning

First licensed vaccine against Enteric Red Mouth (ERM), USA

1984

Step 03

Fish vaccine industry forming

The first seminar on fish vaccination held in Paris

Present

Step 04

Industry scale

More than 210 licensed vaccines

2. The status of global fish vaccines

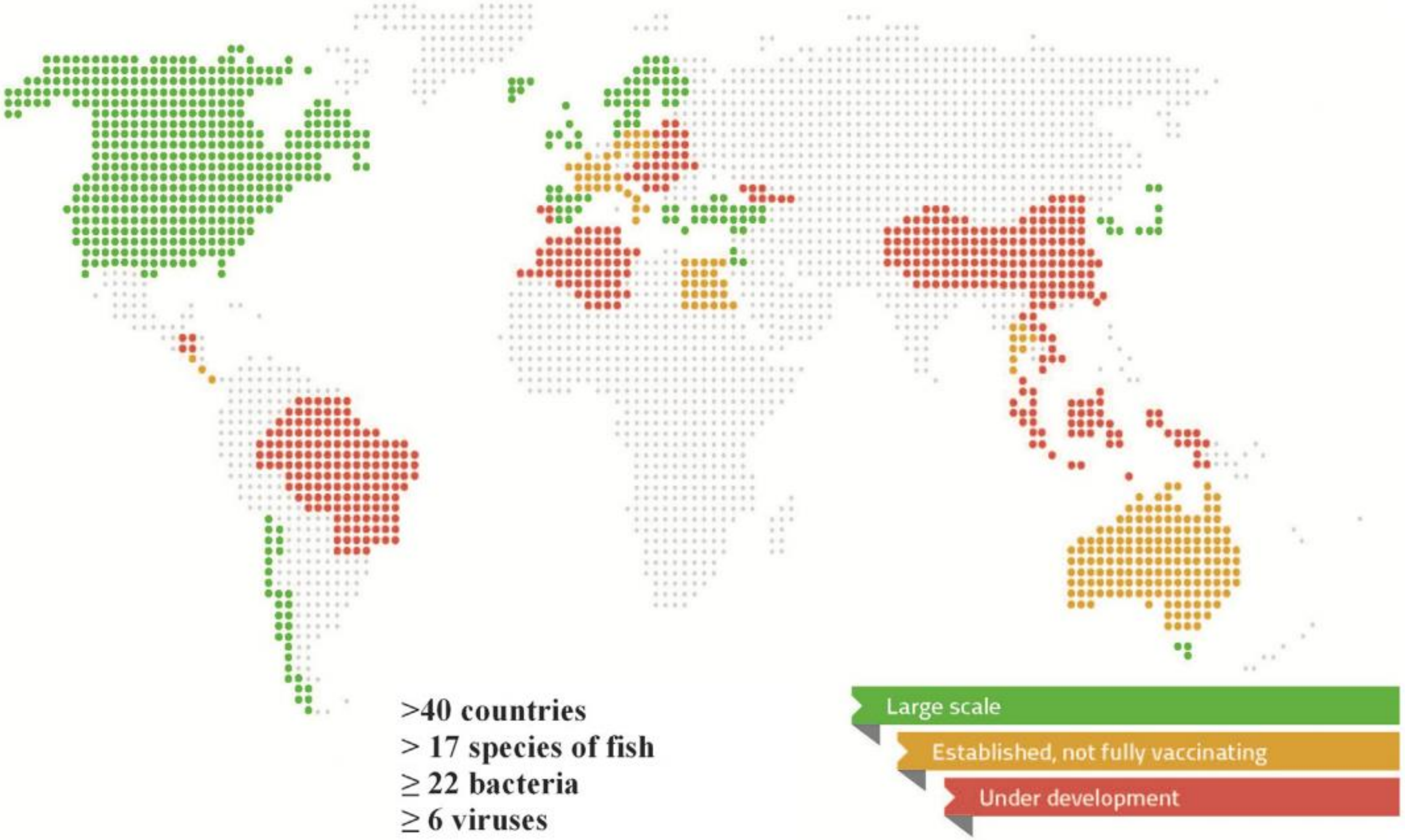


Figure1. Figure1. A categorisation of the countries according to the use and implementation of finfish vaccination. Green shows countries where vaccination is commonly used. Yellow are countries where vaccination is used, but not fully implemented. Red are countries where finfish vaccination is under development. (For interpretation of the references to colour in this fifigure legend, the reader is referred to the web version of this article.) （Brudeseth BE, et al.， 2013）

Vaccines are available for more than 17 species of fish and protect against more than 22 different bacterial diseases and 6 viral diseases. Vaccines are available in more than 40 countries.

Currently 19 major companies market fish vaccines globally and many small companies also exist.(Adams,2019)

Table 1. Incomplete statistics of production validation of fishery vaccine in global

Country	licensed number (statistical year)
USA	26 (By 2012)
Canada	47 (By 2012)
Norway	26 (By 2019)
Chile	45 (By 2019)
Japan	29 (By 2018)
Korea	29 (By 2019)
China	7 (By 2020)
Other countries	1 (Israel), 1(Vietnam), 1 (Singapore)……
Total	>210

（data from ：Shuqin Wu， 2014 ；Hwang， 2019 ；Matsuura， 2019）

3. Overview of licensed fish vaccines that have been used in global aquaculture

viral vaccine

Disease	Pathogen	Major Fish Host	Vaccine Type	Antigens/Targets	Delivery Methods	Country/Region*	Further Information
Viral Diseases							
Infectious hematopoietic necrosis	IHNV Rhabdovirus	Salmonids	DNA	G Glycoprotein	IM	Canada	https://www.dfo-mpo.gc.ca/aquaculture/rp-pr/acrdp-pcrda/projects-projets/P-07-04-010-eng.html
Infectious pancreatic necrosis	IPNV Birnavirus	Salmonids, sea bass, sea bream, turbot, Pacific cod	Inactivated	Inactivated IPNV	IP	Norway, Chile, UK	www.pharmaq.no
			Subunit	VP2 and VP3 Capsid Proteins	Oral	Canada, USA	www.aquavac-vaccines.com
			Subunit	VP2 Proteins	IP	Canada, Chile, Norway	http://www.msd-animal-health.no/
Infectious salmon anemia	ISAV Orthomyxovirus	Atlantic salmon	Inactivated	Inactivated ISAV	IP	Norway, Chile, Ireland, Finland, Canada	www.pharmaq.no
Pancreatic disease virus	SAV *alphaviruses*	Salmonids	Inactivated	Inactivated SAV	IP	Norway, Chile, UK	https://www.merck-animal-health.co
Spring viremia of carp virus	SVCV Rhabdovirus	Carp	Subunit	G Glycoprotein	IP	Belgium	doi: 10.1007/s13337-013-0186-4
			Inactivated	Inactivated SVCV	IP	Czech Republic	Dixon P. et al.,2017
Koi herpesvirus disease	KHV *Herpesvirus*	Carp	Attenuated	Attenuated KHV	IMM or IP	Israel	doi: 10.1007/s13337-013-0186-4
Infectious spleen and kidney necrosis	ISKNV Iridovirus	Asian seabass, grouper, Japanese yellowtail	Inactivated	Inactivated ISKNV	IP	Singapore	https://www.aquavac-vaccines.com/
Grass Carp Hemorrhage	GCRV	Carp	Attenuated	Attenuated GCRV	IP	China	

IHNV: Infectious hematopoietic necrosis virus; IPNV: Infectious pancreatic necrosis virus; ISAV: Infectious salmon anemia virus; SVCV: Spring viremia of carp virus; KHV: Koi herpesvirus; ISKNV: Infectious spleen and kidney necrosis virus; GCRV:Grass carp reovirus; IM: Intramuscular injection; IP: Intraperitoneal injection; IMM: Immersion; * denotes country or region where the vaccine is licensed and sold.

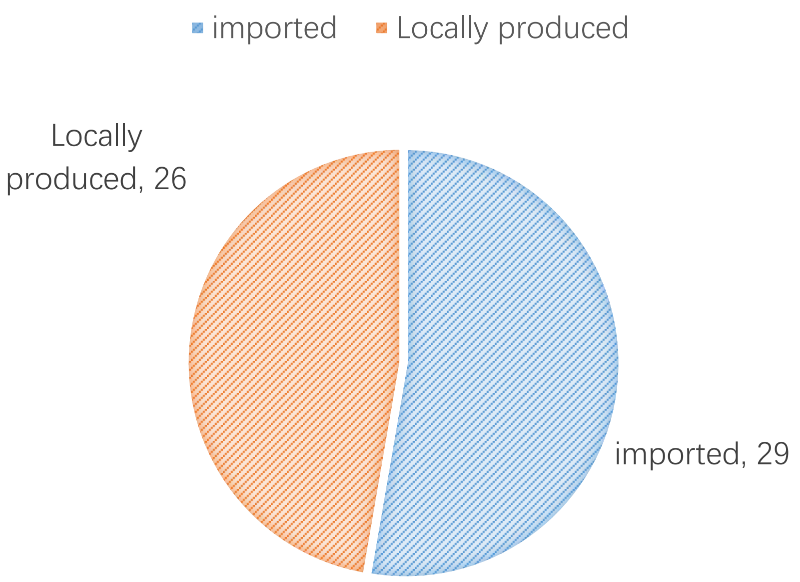
Modified from doi: 10.3390/microorganisms7110569

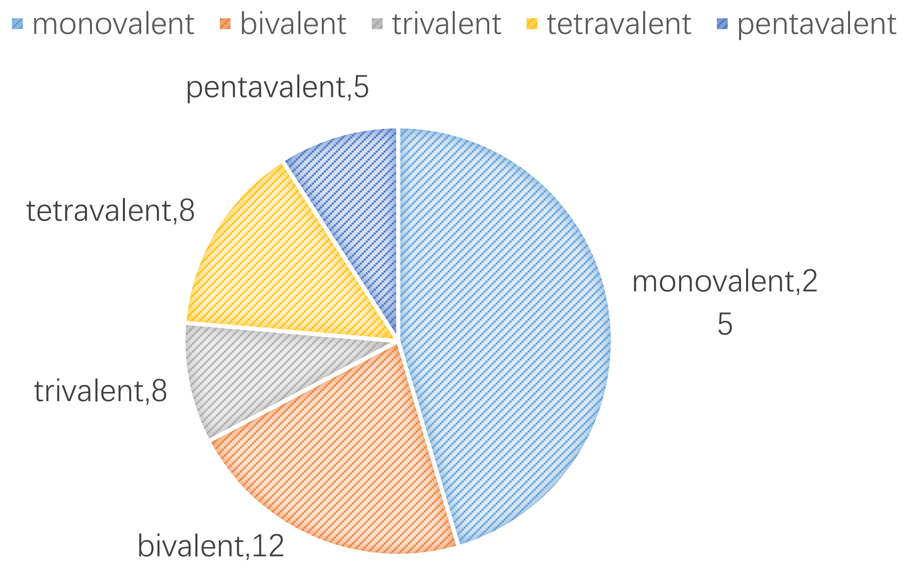
Continued

bacterial vaccine

Bacterial diseases							
Enteric redmouth disease (ERM)	*Yersinia ruckeri*	Salmonids	Inactivated	Inactivated *Y. ruckeri*	IMM or oral	USA, Canada, Europe	http://www.msd-animal-health.ie/products_ni_vet/aquavac-erm-oral/overview.aspx; https://www.msd-animal-health-hub.co.uk
Vibriosis	*Vibrio anguillarum;Vibrio ordalii;Vibrio salmonicida*	Salmonids, ayu, grouper, sea bass, sea bream, yellowtail, cod, halibut	Inactivated	Inactivated Vibriosis spp.	IP or IMM	USA, Canada, Japan, Europe, Australia	https://www.merck-animal-health.com/species/aquaculture/trout.aspx;
Furunculosis	*Aeromonas salmonicida* subsp. *salmonicida*	Salmonids	Inactivated	Inactivated A. salmonicida spp.	IP or IMM	USA, Canada, Chile, Europe, Australia	https://www.msd-animal-health-me.com/species/aqua.aspx
Bacterial kidney disease (BKD)	*Renibacterium salmoninarum*	Salmonids	Avirulent live culture	*Arthrobacter davidanieli*	IP	Canada, Chile, USA	Salonius K. et al., 2005
Enteric septicemia of catfish (ESC)	*Edwarsiella ictaluri*	Catfish	Inactivated	Inactivated *E. ictaluri*	IP	Vietnam	https://www.pharmaq.no/
Columnaris disease	*Flavobacterium columnaris*	All freshwater finfish species, bream, bass, turbot, salmon	Attenuated	Attenuated *F. columnare*	IMM	USA	doi: 10.1016/j.fsi.2010.11.001
Pasteurellosis	*Pasteurela piscicida*	Sea bass, sea bream, sole	Inactivated	Inactivated *P. pscicida*	IMM	USA, Europe, Taiwan, Japan	ALPHA JECT 2000
Lactococciosis	*Lactococcus garviae*	Rainbow trout, amberjack, yellowtail	Inactivated	Inactivated *L. garviae*	IP	Spain	https://www.hipra.com/
Streptococcus infections	*Streptococcus* spp.	Tilapia, yellow tail, rainbow trout, ayu, sea bass, sea bream	Inactivated	Inactivated *S. agalactiae* (biotype 1)	IP	Taiwan Province of China, Japan, Brazil, Indonesia	https://www.aquavac-vaccines.com/products/aquavac-strep-sa1/
				Inactivated *S. agalactiae* (biotype 2)	IP		https://www.aquavac-vaccines.com/products/aquavac-strep-sa/
				Inactivated *S. iniae*	IP or IMM		https://www.aquavac-vaccines.com/products/aquavac-strep-
Salmonid rickettsial septicemia	*Piscirickettsia salmonis*	Salmonids	Inactivated	Inactivated *P. salmonis*	IP	Chile	Evensen, 2016; https://www.pharmaq.no/products/injectable/
Motile *Aeromonas* septicemia (MAS)	*Aeromonas* spp.	Striped catfish	Inactivated	*A. hydrophila (serotype A and B)*	IP	Vietnam	https://www.pharmaq.no/; ALPHAJECT Panga 2
Wound Disease	*Moritella viscosa*	Salmonids	Inactivated	Inactivated *M. viscosa*	IP	Norway, UK, Ireland, Iceland	https://www.pharmaq.no
Tenacibaculosis	*Tenacibaculum maritimum*	Turbot	Inactivated	Inactivated *T. maritimum*	IP	Spain	https://www.hipra.com/

The status of fish vaccines application in Chile





- In Chile, vaccines designed for salmonids have been licensed over the last 30 years.
- There are more than 45 registered vaccines for salmonids.
- The first vaccine against piscirickettsiosis was licensed in 1999, now 32 different vaccines with an SRS component.
- Despite the high number of different registered vaccines for different pathogens and directed for different salmonid species, not all of them are widely use in the Chilean aquaculture.
- The Chilean producers used 379,600 kg antimicrobial in 2020 (353,000 mg per tonne), 2200 times more than Norway.
- The antibiotic use maybe due to the poor efficiency of SRS vaccine that can not protects for the full farm cycle.

The status of fish vaccines application in China

Pathogen	Host	Antigens	Delivery route	Stage	
				The new drug certificate	Production approval
GCRV	Grass carp	Inactivated GCRV	IP	1990	None
GCRV	Grass carp	Attenuated GCRV	IP	2010	2011，2014，2019
Aeromonas hydrophila	freshwater fish	Inactivated *A. hydrophila*	IP/IMM	2001	2011，2020
Vibrio alginolyticus,Vibrio anguillarum,Edwardsiella tarda	Japanese flounder	anti-idiotype antibody of *V. alginolyticus,V. anguillarum,E. tarda*	IP/IMM	2006	2017
ISKNV	Mandarin fish	Inactivated ISKNV	IP	2019	None
V. anguillarum	*Scophthalmus maximus*	Attenuated *V. anguillarum*	IP	2019	None
E. tarda	*Scophthalmus maximus*	Attenuated *E. tarda*	IP	2015	2016

IP: Intraperitoneal injection; IMM: Immersion

A total of 7 vaccines have obtained new drug certificates, of which 4 have obtained production approval.

Pictures of some fish vaccine products in China.

From http://js.xumurc.com/main/shownews_37967.html

From http://www.winsun-gd.com/a/webbase/chanpinzhanshi/shuichanyimiaoxilie/2015/1228/469.html

http://www.xaskystar.com/



PART

3

How to use fish vaccines?

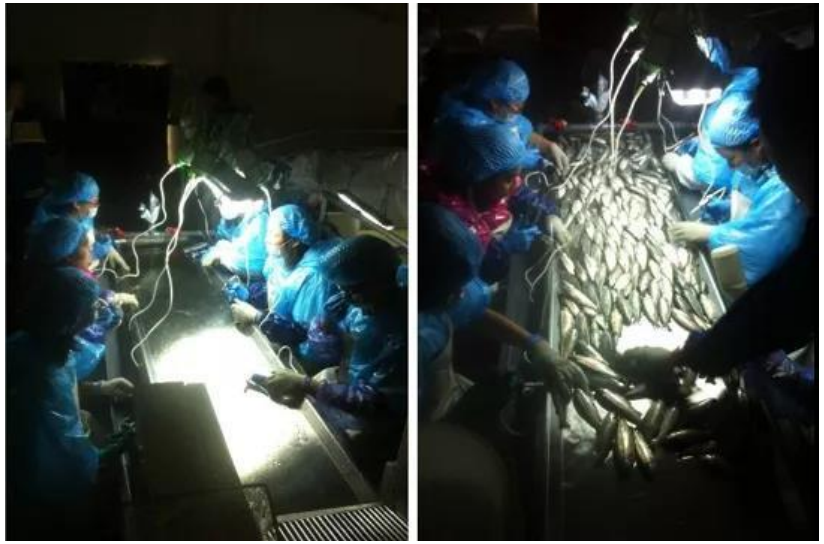
Vaccine delivery methods/routes of administration

Delivery methods	Advantages	Disadvantages
Oral vaccination	1.Easy to use: 2.Saves labor: 3.Not time consuming; 4.Lower stress: 5.Easiest method for mass vaccination of all sizes of fish.	1.Large quantities of antigen required; 2.Requires all fish to be fed; 3.Protection generally weak and of diffcult to determine: 4.Exact dose of antigen received is difficult to determine: 5.Repeated vaccination reduce cell mediated toxicity.
Injection vaccination (intramuscular vaccination,intraperitoneal vaccination)	1.Longer protection: 2.Suitable for large fish; 3.Highly efficient in generating both humoral and cellular cytotoxic responses; 4.Multiple antigens from different pathogens can be delivered; 5.Minimal wastage of vaccine;	1.Unsuitable for small fishes; Needs sophisticated machinery or highly skilled workforce; 2.Significant handling stress; Risk of post vaccination; 3.Fungal infections and local reactions; 4.Labor and time consuming; 5.Use of anesthetic is required; 6.Induce latency to eat
Immersion vaccination （dip vaccination,bath vaccination）	1.Moderate stress for fish; 2.Lower labor costs; 3.Less risk to vaccination team; 4.Cost effective for small fish; 5.High efficacy using attenuated live vaccines	1.Need large amount of vaccine; 2.Low protection with short duration; 3.Low efficacy for inactivated vaccines; 4.Cost prohibitive for large fish

Modified from DOI: 10.1080/23308249.2016.1261277

Injection by hand

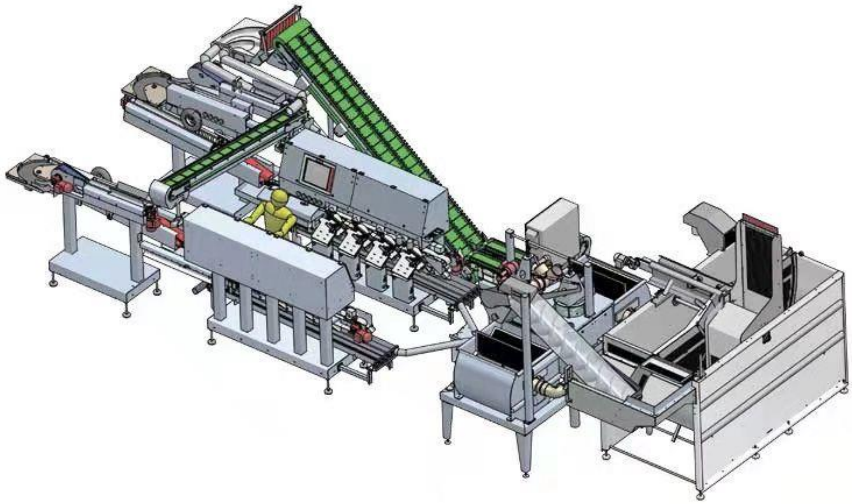
From: www.fishfirst.cn



From: aqualifeservices.com

Injection by machine

From: yourvismawebsite.com/lumic-as



Fully automatic inoculating machine: en.skalamaskon.no

Immersion vaccination

Oral vaccination

Data from :Marian McLoughlin



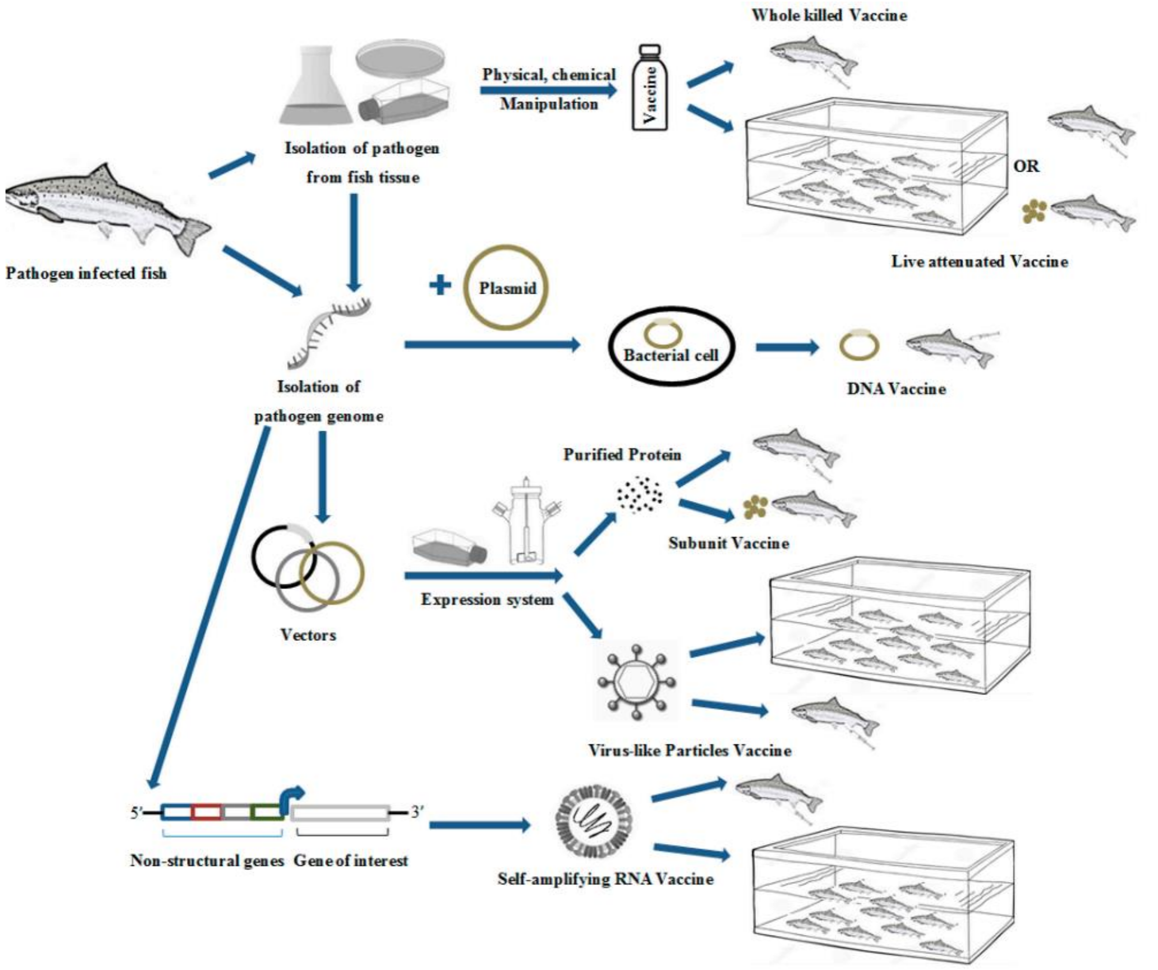
PART

4

Fish vaccines development in the future

1. Fish vaccines classified by antigen form

Antigen form	Advantages	Disadvantages
inactivated antigen	Amenable to autogenously; Safe for use; high effect	Too costly and less than satisfactory for viruses
Attenuated antigen	Can replicate, induce cellular and humoral immunity; Do not require an adjuvant Mimic natural infection and immune response; Amenable to immersion	Safety concerns both in terms of the vaccinated animals and in terms of environmental aspects; Danger for reversion to virulence; Not good a stimulating innate immunity
Recombinat protein	Ability to produce sufficient quantities of the protective proteins; Safe and low cost method	Disturbance in glycolysation of the proteins and restoration of the tertiary structure
Vector technology	High levels of heterologous antigen expression in the cytoplasm; Low-level vector protein expression, induction of apoptosis in infected cells Biosafety production;	Lack of data regarding field performance
Live non pathogenic recombinant microorganism	Low cost of production	Limiting their potential used as genetically modified organisms
DNA vaccine	Induce humoral and cellular immunity	Some obstacles limiting the potential uses of DNA vaccines such as some pathogens possess non protein immunogens
Synthetic peptide vaccine	Possibility for construct a vector encoding several antigens	Lack of data regarding field performance
Anti-idiotype antibody vaccine	Safe for use	Lack of data regarding field performance



From doi:10.3390/microorganisms7110569

Modified from DOI: 10.1080/23308249.2016.1261277

2. Characteristics of global fish vaccine development and application

A Most of vaccines are inactivated vaccines.

B Live attenuated vaccine can not to be licensed in some countries.

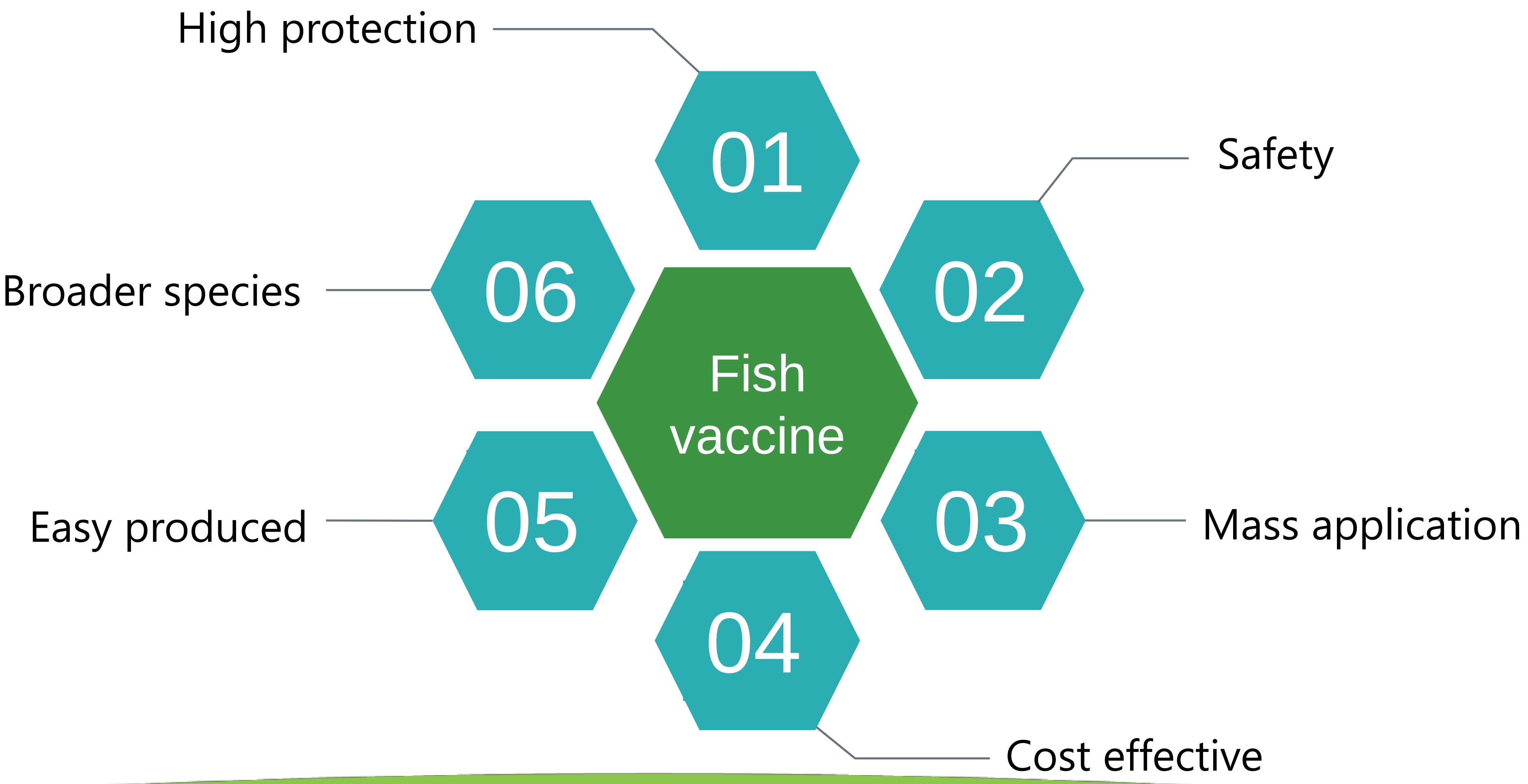
C The main method of vaccine delivery is injection.

D There are few vaccines against parasites to be used.

E The vaccine is mainly used in high-value fish, such as salmon.

F Few vaccines used in low-value fish, such as *Cyprinidae* and tilapia.

3. The ideal fish vaccines



4. Future trends and technologies in fish vaccinology

- More efficient novel adjuvants and delivery systems will be developed, and the efficacy of traditional adjuvants is further improved.

- Defined genetic modifications replace the traditional random mutations in live vaccines to increase controllability and security.

- More new vaccines will be developed, such as DNA vaccine and mRNA vaccine.

- Vaccines are needed for parasites, because these pathogens controlled by chemicals that cause environmental issues and limitation for human consumption.

- Emergency, or autogenous vaccines, can be a useful alternative.

- ....

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REVIEWS IN Aquaculture

REVIEW

Autogenous vaccination in aquaculture: A locally enabled solution towards reduction of the global antimicrobial resistance problem

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The benefits of autogenous vaccination to animal welfare, transboundary biosecurity, local farmer and industry economics, and to public health, favour implementation in aquaculture as a locally enabled solution to the global problem of antimicrobial resistance.

To be vaccinated, or not to be vaccinated?

That is different!

THANKS FOR YOUR ATTENTION!