

Control programs for infectious bovine rhinotracheitis (IBR) in European countries: an overview

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Review

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Abstract

Infectious bovine rhinotracheitis (IBR), caused by *Bovine alphaherpesvirus 1* (BoHV-1), is a disease of cattle responsible for significant economic losses worldwide. IBR is under certain communitarian regulations. Every member state can approve its own national IBR control program for the entire territory – or part of it – and can demand additional guarantees for bovinds destined to its territory; therefore, every member state can be officially declared as entirely or partly IBR-free. The aim of this review is to provide an overview of IBR control and eradication programs in European countries. BoHV-1 control schemes were first introduced in the late 1970s, mainly in Northern and Central Europe. Depending on the seroprevalence rate, control strategies rely on identification and removal of seropositive animals or the use of glycoprotein E (gE)-deleted marker vaccines in infected herds. The implementation of a novel law for disease eradication at the EU level and of a European IBR data flow could make the goal of IBR eradication in all European countries easier to achieve.

Introduction

Infectious bovine rhinotracheitis (IBR), caused by *Bovine alphaherpesvirus 1* (BoHV-1), is a disease of cattle that is responsible for significant economic losses worldwide. BoHV-1 is a member of the genus *Varicellovirus* in the subfamily *Alphaherpesvirinae*, which belongs to the *Herpesviridae* family. The virus is associated with major clinical syndromes, namely IBR, infectious pustular vulvovaginitis (IPV), and infectious pustular balanoposthitis (IPB). The virus also causes other clinical syndromes such as abortion, infertility, conjunctivitis, enteritis, and encephalitis (Nandi *et al.*, 2009). The main sources of the virus are nasal exudates and cough droplets, genital secretions, semen, fetal fluids, and tissues. These materials can be transmitted by direct contact with infected animals or by indirect contact with infected material and personnel. BoHV-1 can become latent following a primary infection with a field isolate or vaccination with an attenuated strain. The virus is usually detectable in the sensory ganglia of the trigeminal nerve in IBR, and in the sacral spinal ganglia in IPV/IPB (Wentink *et al.*, 1993). Latency may also occur in tonsillar lymphoid cells and peripheral blood lymphocytes (Ackerman and Wyler, 1984). Viral reactivation may occur owing to stressful stimuli associated with delivery, transport or animal mixing, insufficient herd management, co-infections, superinfection, treatments with corticosteroids, or parturition (Winkler *et al.*, 2000). As a result, the reactivated virus may be re-excreted, and an increased neutralizing antibody titer may be observed. Latently infected animals should always be considered as a potential source of infection (Bitsch, 1973), though some types of vaccines can considerably reduce the amount of virus excreted following reactivation (Mars *et al.*, 2001). The commercially available vaccines at present can be divided into two main categories: (i) traditional vaccines and (ii) marker vaccines. The first category, which was the only category of vaccines available until the 1990s, usually prevents severe clinical signs of disease and reduces the amounts of viral particles shed after infection; however, their use could not restrict infection spread in some herds or regions. Moreover, their use interferes with routine serological diagnosis and epidemiological surveys essential for control programs (Van Oirschot *et al.*, 1996). In the 1990s, a new vaccine category was developed by deleting one of the non-essential viral glycoproteins, mainly glycoprotein E (gE) of BoHV-1, which was made commercially available. This vaccine allows distinction of traditionally vaccinated cattle and infected animals (gE-positive) from those vaccinated with the gE-deleted marker (gE-negative) by using a suitable serological diagnostic test (Van Oirschot *et al.*, 1996). Therefore, gE-deleted marker vaccines can serve as a valuable tool for disease control strategies. Vaccination against BoHV-1 has been employed since the first appearance of the related disease. Indeed, BoHV-1 was recognized as the causative agent of IBR in cattle in the 1950s, in the USA (Madin *et al.*, 1956), and the first attenuated live vaccine was produced around the same time (Kendrick *et al.*, 1956). Soon after its spread

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in the USA, IBR was reported in many European countries (Moretti *et al.*, 1964; Straub, 1975). Despite the low mortality levels, BoHV-1 infection caused considerable economic losses everywhere the virus was introduced and spread. According to former EU regulations, IBR was listed in annex E-II of Council Directive 64/432/EEC (European Commission, 1964). Thus, every member state could receive approval for a national IBR control program for its entire territory or a part of it, and for additional guarantees for bovinds destined for its territory (European Commission, 1964, article 9), and every member state could be declared as officially IBR-free in the entire territory or in a part of it (European Commission, 1964, article 10). Furthermore, the IBR-free status was one of the required animal-health conditions for intra-community trade and importation of cattle semen (European Commission, 1988) and embryos (European Commission, 1989) from third countries. Nevertheless, according to previous EU regulations, IBR was not listed in annex E-I of Council Directive 64/432/EEC (European Commission, 1964); hence, IBR was not a notifiable disease in the EU. Currently, Council Directive 64/432/EEC has been repealed by Regulation 2016/429/EU (European Commission, 2016a), the so-called 'Animal Health Law', and its resulting Regulations as of 21 April 2021. According to the present legislation, IBR is listed in annex II of Animal Health Law (European Commission, 2018a), is inserted in categories C + D + E (European Commission, 2018b), and disease outbreaks are notifiable if they occur in IBR-free member states or in IBR-free zones of EU countries (European Commission, 2020b). Required conditions to achieve and maintain disease-free status, as well as control strategy and surveillance organization, are reported into a new regulation (European Commission, 2020c). Sanitary measures applied to material germinal for IBR are present in a new law in force (European Commission, 2020d), while rules regarding animal health requirements for movements within the Union are codified in a new act (European Commission, 2020e). IBR can be subjected to an optional eradication program in the Member States (European Commission, 2020b). Furthermore, according to the former EU law, different European countries implemented IBR control schemes in their territories, and a few of them obtained IBR-free status (European Commission, 2017b) followed by restraint of cattle trade (European Commission, 2004b). Currently, a new regulation regards the approval of the disease-free and non-vaccination status of certain Member States or zones or compartments thereof with regard to certain listed diseases and the approval of eradication programs for those listed diseases, such as IBR (European Commission, 2021). Finally, detailed standards for the international control of IBR/IPV are contained in the World Organisation for Animal Health Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (OIE, 2018). The requirements that a country, zone, or herd should satisfy to qualify as free from IBR/IPV and to maintain its status as free are reported; recommendations are also delineated for the importation of cattle destined for herds free from IBR/IPV or intended for herds not qualified as free from the disease, as well as recommendations for the importation of fresh or frozen semen and of oocytes or embryos. The aim of this review is to provide an overview of IBR control and eradication programs in European countries. A twofold data source was required in this study. Literature references were retrieved by querying PubMed (National Library of Medicine) and Scopus (Elsevier) databases, accessed until 12 July 2021; particularly, the following keywords 'IBR eradication', 'IBR control', and

'IBR surveillance' were searched in all available papers and possible duplicates removed. Legislative references were obtained by querying EUR-Lex, the online gateway to EU legal documents, for most European references; for some cases, such as Switzerland and Ireland, respective official online application portals were queried.

Control and eradication strategies in the EU

The first IBR control programs were implemented beginning in the 1970s to 1980s. Since the EU allowed IBR-free member states to request import conditions for cattle, semen, and embryos (Noordegraaf *et al.*, 2000), more efforts were undertaken in the late 1990s to achieve IBR eradication in European territory (Beer *et al.*, 2003). To date, a variety of IBR control programs have been performed or are in progress in the EU, whose features depend on epidemiological and economic issues. In conditions of low BoHV-1 seroprevalence, culling of seropositive animals without vaccination (test and slaughter strategy) has been the most successful method for eradication. In addition, it is advisable to create an IBR-free breeding stock by gradually removing all seropositive cattle from a conventional breeding lot and replacing them with seronegative progeny (Ackermann and Engels, 2006). Scandinavian countries (Denmark, Finland, Norway, and Sweden), as well as Austria, Switzerland, and some Italian regions, have successfully achieved IBR eradication by following this strategy. Vaccination using gE-deleted marker vaccines, followed by seropositive animal removal, is an appropriate tool in conditions with medium/high BoHV-1 seroprevalence. This approach is the so-called DIVA strategy (Differentiating Infected from Vaccinated Animals). Because the total seroprevalence of gE-positive animals can reach up to 5%, the remaining seropositive animals can be removed (Vonk Noordegraaf *et al.*, 1998). Some countries, such as Belgium and the Netherlands, have adopted the vaccination strategy to control the disease. Once the eradication target is achieved, it is essential to reinforce this goal by implementing a subsequent surveillance program. The purpose of surveillance is to ensure early detection of infection in IBR-free herds, so that infection spread to other certified herds can be prevented (Graat *et al.*, 2001). In dairy cattle, enzyme-linked immunosorbent assay (ELISA) tests of bulk-tank milk for antibodies provide a useful and low-cost method for determining BoHV-1 seropositive status (Nylin *et al.*, 2000).

Austria

In 1987, a voluntary IBR eradication program involving breeding cattle was implemented in the Styria region; this program used 'test and removal' procedures for serologically positive animals (Kofer *et al.*, 1999). In 1990, IBR control became compulsory for all cattle herds in the country, involving all animals >2 years of age, without distinction between animals for slaughter, breeding, or production; therefore, the legal provisions prohibited vaccination and required reactors to be slaughtered (Republic of Austria, 1989). In 1994, when Austria did not yet belong to the European Economic Community (EEC), the European Free Trade Association (EFTA) Surveillance Authority approved the national program for the eradication of IBR, which had been applied since 1990; simultaneously, it laid down additional guarantees for cattle intended for breeding and production and destined for Austria, in order to protect the progress already made and to ensure that the program was successfully concluded

(European Free Trade Association 'EFTA' Surveillance Authority, 1994d). In 1995, when Austria joined the EEC, the eradication program was approved by the European Commission from 1995 to 1997 (European Commission, 1995a), and Austria was granted additional guarantees (European Commission, 1995c). During the period from 1995 to 1997, a large number of IBR outbreaks were recorded; epidemiological investigations showed that most were caused either by illegal cattle imports or by legally imported cattle provided with relevant certificates. Therefore, the biennial rhythm of controls was changed to an annual rhythm, beginning from 1997 (Kofer *et al.*, 1999). In the same year, the ongoing eradication program was approved for a further period of 3 years (European Commission, 1997). In 1998, the entire territory of Styria and some other provinces were considered as IBR-free and received additional guarantees to protect their territory (European Commission, 1998b). In 1999, IBR-free status was obtained by the entire country (European Commission, 1999). The sampling plan for IBR was changed in 2007, when bulk milk testing was established at the national level, and in 2013, when different disease control plans were harmonized (Roch and Conrady, 2021). Over the years 2000–2010, in Austria, single positive reactions have been detected (Raaperi *et al.*, 2014). The last outbreak notification was in 2015 during an export examination and caused increased animal control; IBR-positive tested cattle were detected and removed (Roch and Conrady, 2021). The additional guarantees remained unaffected. Currently, these cases do not invalidate IBR-free status of the whole country, as reported in the latest regulatory action (European Commission, 2021).

Belgium

From 1991 to 1994, a voluntary program for IBR control was set up covering 70 herds in the Wallon region, where rapid culling of seropositive animals was unfeasible because of the high prevalence rate (60%). Therefore, disease control was attempted with repeated vaccinations and the use of severe biosecurity measures. This was the first experience for Belgium on a regional basis (Wergifosse *et al.*, 1997). Subsequently, the European Commission granted approval to Belgium for an eradication program covering the whole of its territory, and additional guarantees were granted in 2014 (European Commission, 2014).

Czech Republic

The Czech Republic has an IBR control program in place since 2005 (Nettleton and Russel, 2017). A mandatory eradication program for all cattle keepers on the whole territory started in 2006, was approved in 2008 (European Commission, 2008) and finished in 2016, when most holdings had no IBR-positive animals. Eradication measures continued to be applied in the country, until all bovine animals were kept on IBR-free holdings. In 2020, Czech Republic submitted to the European Commission supporting documentation in order for the whole of its territory to be considered IBR-free, and obtained the current status for the disease; its government requested and obtained approval to apply additional guarantees in accordance with article 10 of Directive 64/432/EEC (European Commission, 2020a).

Denmark

In Denmark, BoHV-1 first appeared in the early 1970s, probably with infected cattle imports, and quickly spread, at first among

bulls at some artificial insemination (AI) centers, and then among a greater number of herds (Bitsch, 1978). A systematic eradication program began in 1984, when the seroprevalence among dairy herds was about 9%. It was based on serological testing of all cattle in the herd and slaughter of seropositive animals, while vaccination was not considered acceptable. Therefore, only seronegative cattle from negative herds could be transferred between herds. Throughout the eradication plan and during the surveillance phase, bulk-tank milk was used to monitor the IBR status of dairy herds; milk samples were tested at 3 or 4 months, while monthly testing of bulk-tank milk was conducted from October to May in the Jutland region, because herds in this area had a higher risk of BoHV-1 infection. In addition, blood samples were obtained randomly at slaughterhouses. As a part of the eradication plan, a central database that contained the IBR status for each tested herd, other data such as herd size and age of animals at sampling, and diagnostic results at testing was established (Nylin *et al.*, 2000). At the beginning of 1991, a few seropositive herds were still present, but no acute outbreaks were recorded in these herds. The surveillance plan was initiated from March 1991, and Denmark obtained IBR-free status from the European Commission in 1992 (European Commission, 1993). Nevertheless, during 1991–1995, viral reintroduction occurred, and new seropositive herds were recorded in the Jutland region close to the German border and in other areas as well. Two different routes of viral introduction seemed to be possible: an accidental contact with infected German cattle near the German-Danish border, probably via aerosol, or an unauthorized import of infected cattle. As a part of follow-up investigations for the viral reintroduction, a special survey was carried out by testing individual serum samples from 10% of cattle in each herd. All data for suspected or infected herds in 1991–1995 were collected in the IBR database and used to develop an adequate national surveillance plan again. Field viral strains isolated from these outbreaks were subjected to restriction fragment analysis. The results demonstrated the presence of different types of BoHV-1 (Nylin *et al.*, 1998). The last IBR outbreak reported in Denmark was in 2005, near their German border (Raaperi *et al.*, 2014). Nevertheless, Denmark's status as an IBR-free country has been kept to date (European Commission, 2021).

Estonia

In Estonia, no systematic control programs have been applied against BoHV-1, except in bulls used for semen collection at AI centers. All animals introduced to the AI center must be isolated in their herd of origin, tested and confirmed to be negative for BoHV-1 antibodies 30 days before movement; therefore, bulls used for semen collection are tested serologically once a year. Nevertheless, in this country, some studies were carried out to detect the efficacy of vaccination programs in lowering seroprevalence within dairy herds and to follow the dynamics of infection in non-vaccinated herds (Raaperi *et al.*, 2012).

Finland

In Finland, serological testing for IBR started in 1965, and seropositive samples were found for the first time in 1970–1971, from bulls at an AI station. BoHV-1 may have been introduced in 1968 by an infected AI bull imported from Denmark, which infected other AI station mates. It is quite possible that infected semen from seropositive AI bulls was used between 1968 and

1979, and spread BoHV-1 infection to a number of herds where the virus persisted for over a decade (Nuotio *et al.*, 2007). In Finland, IBR is a notifiable disease; vaccine use was not considered feasible in the IBR control policy, so a decisive ‘test and slaughter’ strategy was adopted successfully. Therefore, systematic serological testing of AI bulls began in 1978. The rate of testing increased between 1986 and 1989. Since 1991, each dairy herd was tested annually, and since 1993, random samples of beef animal sera were also tested. The infection resurfaced in 1990 and was identified because of clinical suspicion, bulk-tank milk surveillance and epidemiological investigations. Five herds were involved and subjected to all provided control measures, including stamping out. The infection was eradicated in 1994, and additional guarantees for cattle destined for Finland were approved by the EFTA Surveillance Authority first, and then by the EEC (European Free Trade Association ‘EFTA’ Surveillance Authority, 1994a; European Commission, 1994). Therefore, the surveillance scheme included annual serological tests in bulk-tank milk samples and in beef animals at slaughterhouses (Nuotio *et al.*, 2007).

France

In France, a voluntary eradication program based on the ‘test and removal’ strategy without vaccination was started in 1996. In 2006, a mandatory control plan based on serological testing together with vaccination and/or positive animal removal was implemented. As an increasing number of certified BoHV1-free herds were observed at the national level for 10 years, official authorities approved a compulsory program since 2016 in order to speed up the eradication plan (Valas *et al.*, 2019). In the period 2016–2020, the goals to reduce herd prevalence and to increase herd number with IBR-free qualification were achieved. In 2020, France submitted to the European Commission supporting documentation and obtained approval of its national program for IBR eradication, covering all French metropolitan departments, except for Corsica; its government requested and obtained approval to apply additional guarantees in accordance with article 9 of Directive 64/432/EEC (European Commission, 2020a).

Germany

In Germany, BoHV-1 infection control was mandated by law in 1997 (Nettleton and Russel, 2017). The control program was approved by the European Commission in 2004 (European Commission, 2004a). In the same year, the approved German IBR control plan and additional guarantees for intra-Union cattle trade relating to IBR were put together in the same Decision (European Commission, 2004b). In 2007, Germany requested and obtained the right to declare a part of its territory free of BoHV-1 infection and to apply additional guarantees for the administrative units of Regierungsbezirke Oberpfalz and Oberfranken in the federal state of Bavaria (European Commission, 2007). In 2010, two other administrative units in the federal state of Bavaria were declared free of BoHV-1 infection (European Commission, 2010). In 2011, the three remaining administrative regions in the federal state of Bavaria were considered free of BoHV-1 infection and obtained the right to be covered by additional guarantees (European Commission, 2011). In addition to the Bavaria region, a series of other regions were declared officially IBR-free: the Federal State of Thuringia in 2014 (European Commission, 2014); the Federal States of Saxony,

Saxony-Anhalt, Brandenburg, Berlin, and Mecklenburg-Western Pomerania (European Commission, 2015a); the Federal State of Baden-Württemberg (European Commission, 2015b); the Federal States of Bremen, Hesse, and Lower Saxony (European Commission, 2015c) in 2015; the Federal States of Rhineland-Palatinate, Saarland, and some administrative units in the Federal State of North Rhine-Westphalia in 2016 (European Commission, 2016b); and the Federal States of Hamburg and Schleswig-Holstein in 2017 (European Commission, 2017a). Finally, in the same year, when the last administrative unit, the Federal State of North Rhine-Westphalia, was considered IBR-free, the entire German territory was recognized free of BoHV-1 infection and applied for additional IBR guarantees (European Commission, 2017b).

Hungary

For Hungary, only two reference studies are available, covering the years 1990–2000. According to Tanyi and Varga (1992), in the 1990s, no national data for IBR infection prevalence were available, and the accessible records only provided preliminary data from some old studies. From 1983 to 1988, a survey was conducted by testing 160 farms. Of these, 28 farms (17.5%) were seronegative for BoHV-1; in 105 farms (65.5%), a certain proportion of seropositive cattle without clinical signs of disease was reported; in 27 farms (16.9%), most of the cattle were seropositive and IBR-induced abortions occurred as well. In a survey conducted in two AI stations in 1991, 49.3 and 48.9% of the bulls, respectively, were positive. Progressively, certain attention was paid to the IBR question, and a national eradication plan began in 2002. As part of this program, farmers had to screen their herds for seroprevalence and, subsequently, submit a vaccination program to Veterinary Services for approval, in order to eradicate infection by using gE-deleted marker vaccines (Makoschey *et al.*, 2007).

Ireland

BoHV-1 was first isolated in Ireland in 1971 from a conjunctivitis case; many other cases were reported in the following years, and this number began increasing in the late 1980s. However, BoHV-1 seroprevalence was reported to be low, <20%, even in the periods with a high IBR incidence. Due to legislative requirements (Minister for Agriculture and Food, 2002), all IBR vaccines allowed in Ireland since 2004 were DIVA vaccines (Simon, 2004). However, some recent studies showed a markedly increased seroprevalence in both dairy and beef herds and a widespread distribution of infection in Ireland. For instance, in the 2010s, herd seroprevalence rate was found to be between 28 and 42%, with significant regional differences (Graham, 2013). This increase in the incidence and severity of IBR outbreaks has prompted some local authorities to consider IBR more than a sporadic disease. For instance, Animal Health Ireland (AHI) and Animal Health and Welfare NI (AHWNI), two not-profit partnerships for important non-regulated diseases involving farmers, processors, service providers, and the government, and acting in Ireland and Northern Ireland, respectively, have identified IBR management as a priority in local farms (Graham, 2013). Nevertheless, as of 2015, a coordinated approach to IBR control did not exist in Ireland (Sayers *et al.*, 2015). Currently, a new discussion just started about IBR infection, in order to define structure and implementation of a potential national eradication plan. A new

and innovative spatially explicit, individual-based, regional cattle disease model was proposed. It could be used as an effective tool for decision-makers to facilitate the assessment of IBR eradication strategies in the country (Brock *et al.*, 2021).

Italy

In Italy, the acute respiratory form of the disease was first reported in 1964 (Moretti *et al.*, 1964). Nevertheless, according to former law, IBR is not a notifiable disease (Ruffo *et al.*, 2017a) and, to date, not subjected to a national-level eradication plan for the whole cattle population. Disease control programs started at the regional and provincial levels at the beginning of the 1990s, to facilitate trading. In fact, some regions in North Italy were dependent on cattle trading and faced restrictions on season movements, imposed by the bordering already IBR-free countries. These territories include the Friuli Venezia Giulia region and Trento province on one hand, and the Valle d'Aosta region and Bolzano province on the other hand: the first group obtained approval for its eradication programs from the European Commission, and the second one was considered officially IBR-free (European Commission, 2017b, annex II). Within some years, other Italian territories developed programs to eradicate IBR from their territories by controlling the disease in breeding cattle populations and by using marker vaccines in some cases (Tamba *et al.*, 2021). Furthermore, in 2015 and 2016, the Italian Ministry of Agriculture, Food and Forestry (Ministero delle Politiche Agricole Alimentari e Forestali; MIPAAF) and Italian Ministry of Health approved two surveillance plans for controlling IBR in some beef cattle breeds, which have been recorded in the National Herd Book (Ministero delle Politiche Agricole Alimentari e Forestali, 2015, 2016). The plans are voluntary, and monetary incentives are paid if farmers achieve the annual target seroprevalence range (Maresca *et al.*, 2018).

Luxembourg

Luxembourg obtained approval for its national IBR eradication program covering the whole territory, and for additional guarantees for intra-Union cattle trade from the European Commission in 2017 (European Commission, 2017a).

Norway

IBR is a reportable disease in Norway (Paisley *et al.*, 2001). The first two IBR outbreaks were reported in the early 60s, while the latest single positive herd was found in 1993. Until 1992, importation of live cattle into Norway was prohibited. When the General Agreement on Trade and Tariff (GATT) was approved, this prohibition was discharged and Norway mandated BoHV-1 serological testing for all imported cattle to maintain its high animal-health standards. According to the World Trade Organization (WTO) and EFTA guidelines, in order to apply import restrictions based on freedom from a disease, any member state has to prove to be free from that disease itself. For this reason, Norway began serologically testing its cattle population since 1992. Since 1993, IBR has not been diagnosed clinically or serologically in Norway. In 1994, Norway was recognized as an IBR-free country by the EFTA Surveillance Authority and additional guarantees for bovines to be imported were granted (European Free Trade Association 'EFTA' Surveillance Authority, 1994c). Until 1996, the surveillance plan provided

for annual testing of bulk-tank milk samples from all dairy herds; however, since 1996, this has been reduced to only 10% of the herds. In 2010, Norway requested the EFTA Surveillance Authority to update the previous decision in order to take account new legislative changes covering additional guarantees for intra-Union cattle trade relating to IBR (European Commission, 2004b). The new decision maintained the same guarantees previously granted to Norway and aligned them with the present European criteria (EFTA, Surveillance Authority, 2010).

Slovakia

For Slovakia, only one reference study is available (Mandelik *et al.*, 2021). According to the authors, a voluntary IBR control program was implemented in 1996 but, in the subsequent years, only a small rate of national herds enrolled in this plan. Since 2006, the program became compulsory for all cattle farms in the country. First, serological tests were used to identify infected animals. Then, according to prevalence rate, eradication was based on culling (herd seroprevalence <15%), or on use of gE-deleted marker vaccines in combination with culling (herd seroprevalence >15%). When appropriate, especially in very small farms, all animals were slaughtered, with agreement from the farmers. Depending upon the selected method, seropositive cattle were gradually replaced by animals originating from officially IBR-free herds, in order to limit economic losses. After the replacement of all infected animals, a monitoring program started, to maintain IBR-free herd status. Further measures were implemented, such as strict control on animal movement and farmer education, to improve disease awareness. According to official data, 60.2% of herds were IBR-free in the country in 2020.

Spain

For this country, very poor information is available regarding IBR control plans. According to Villaamil *et al.* (2020), in Galicia (north-west of the country), an official voluntary IBR control plan has been in place since 2004 and now involves a large proportion of the cattle population. The program is based on a serological survey of herds and progressive seroprevalence reduction, by means of replacement control and not by culling animals. Furthermore, additional measures are required, such as the mandatory control for IBR in all purchased animals.

Sweden

In 1994, the EFTA Surveillance Authority granted approval to the Swedish national IBR eradication program until 1997, along with additional guarantees for cattle intended for breeding and production and destined for Sweden, to protect the progress already made and to ensure that the program was successfully concluded (European Free Trade Association 'EFTA' Surveillance Authority, 1994b). In 1995, an official eradication program was approved (European Commission, 1995b). At the same time, the European Commission granted additional guarantees for cattle destined for Sweden, in order to protect territory under the IBR eradication program (European Commission, 1995c). In 1998, Sweden submitted supporting documentation to the Commission and obtained the right to be considered as IBR-free in the whole country (European Commission, 1998a).

Switzerland

The first IBR outbreak in Switzerland was reported in 1978, when data about infection prevalence and its distribution were not available and national laws concerning IBR were yet to be established (Ackermann *et al.*, 1990). Retrospective studies indicate that, in 1978, the proportion of positive farms varied from 1 to 15% regionally. The disease was made notifiable and some measures were provided, such as trading bans for farms with confirmed or suspected IBR cases, the performance of serological tests before movement since 1980 and only allowing movement of seropositive cattle to slaughterhouses. Serological surveys were performed nationwide in order to determine the prevalence and incidence of disease, and since 1983 national law was modified to eradicate IBR. In particular, trade restrictions were extended to all cattle present in a positive farm, seropositive cattle had to be slaughtered, and the ban was lifted from the farm only if two consecutive serological tests within 6 months indicated freedom from BoHV-1 in all cattle. All farms had to be tested for antibodies to BoHV-1 in serum samples once per year or in pooled milk samples twice per year, and IBR vaccines were never licensed. In a first step, all these measures concerned dairy farms only, because fattening animals originated from IBR-free sources and were transported directly to the slaughterhouse. Nevertheless, a serological survey in 1985 indicated that fattening cattle were the last infection reservoir. For this reason, fattening farms were also subjected to restrictive measures related to farm biosecurity management as well as accurate serological tests. At the same time, new laws regulated cattle and semen importation as well to prevent IBR introduction from other countries. Finally, Switzerland eradicated IBR in 1988, 10 years from the first outbreak, by slaughtering about 50,000 seropositive cattle and without using vaccines. Since then, the Swiss Confederation has proven its IBR-free status annually by serological testing of serum and bulk-milk samples from randomly selected farms. Sample size had to be sufficient to exclude an effective prevalence rate higher than 0.2% (Swiss Confederation, 2018). Since 1994, different IBR outbreaks were reported in the country, probably because of viral reintroduction via imported infected cattle. As a result, in 2012, the surveillance program was modified by increasing the number of tested dairy farms number and by testing some other farms associated with IBR risk factors (seasonal cattle movement, high importation or trade rates, nearness to national borders). At present, the Swiss surveillance program provides for annual serological testing in randomly selected farms, high IBR-risk farms, and bulls aged >24 months. Vaccine use is not permitted, and seropositive cattle are considered virus carriers without further virological tests. Particularly, the national law in force in case of outbreaks provides for immediate notification, loss of IBR-free status, farm attachment, abortion-cause analysis, immediate serological tests, and annual random tests (Swiss Confederation, 1995). The European acknowledgement is regulated by a trading agreement between the Swiss Confederation and European Commission since June 1999 (Swiss Confederation, 1999). As a result, additional guarantees were valid for cattle destined for Switzerland according to former European regulations (European Commission, 2004b).

The Netherlands

In the Netherlands, IBR outbreaks were observed for the first time in 1973 and associated with severe clinical signs; BoHV-1 spread in the whole territory in the years thereafter, so the severity of

clinical signs decreased as the infection became enzootic (De Wit *et al.*, 1998). Most of the dairy cattle population became seropositive because of viral dissemination and extensive vaccination: in 1993, about 42% of dairy cows were seropositive and about 85% of herds were infected (Vonk Noordegraaf *et al.*, 1998). Since 1993, local authorities allowed the Dutch cattle industry to begin a voluntary eradication program. In 1996, the Dutch farmers board decided to start a national compulsory eradication program. It began in 1998 and provided vaccination with a marker vaccine for all cattle >3 months of age twice a year; therefore, herds were certified as IBR-free when all cattle >12 months of age tested seronegative in ELISA for gB or gE (De Wit *et al.*, 1998). At the start of the eradication program, about 25% of dairy herds and about 18% of non-dairy herds were certified as IBR-free in the country. These farms were allowed to purchase cattle from other certified herds only; therefore, their status was monitored through monthly bulk-milk tests and semiannual serological tests in dairy herds and non-dairy herds, respectively (Vonk Noordegraaf *et al.*, 2004). Surveillance program demands were determined by means of mathematical models (Graat *et al.*, 2001). Dutch agriculture is characterized by intensive animal production, implemented since the 1980s when cattle concentrations, as well as national and extra-national cattle movements, increased considerably (Van Schaik *et al.*, 1998). The Netherlands has a high cattle importation rate: >900,000 cattle are imported annually, and most of them (94%) are calves fattened for a few months and then sent to the slaughterhouse. Most imported cattle originate from IBR-free or nearly IBR-free countries. Nevertheless, a notable proportion of cattle are imported from countries where the disease is still endemic. When the Netherlands becomes IBR-free, cattle import flow will be the largest threat for virus reintroduction (Santman-Berends *et al.*, 2018).

United Kingdom

IBR was first described in the UK in 1961, when a BoHV-1.2b strain was isolated, being designated as the British-type virus since then (Oxford strain; Graham, 2013). From 1977 to the mid-1980s, a sudden rise in IBR incidence and severity was reported, associated with a high herd morbidity rate and a variable but significant mortality rate. The seropositive cattle rate increased from 5% in the early 70s to 12% in the mid-1980s. A new viral strain was possibly introduced from North America to the UK in that period because of the movement of infected cattle (Edwards, 1988). Subsequently, IBR outbreaks have been constantly reported. According to official sources, in the IBR surveillance data in the UK from 2010 to 2015, the disease has been diagnosed throughout the whole country, but mainly in Scotland, Western regions, and Wales (Veterinary Investigation Diagnosis Analysis, VIDA, 2015). Within this period, a decrease in the number of submitted IBR cases has been reported, confirming better infection control, although these results may have been biased by the use of different diagnostic methods (Ackermann *et al.*, 1990). In 2017, UK authorities submitted supporting documentation to the Commission that let Jersey territory to be recognized as free of BoHV-1 infection and applied for additional IBR guarantees (European Commission, 2017a).

Discussion

The IBR status and history of several European countries were investigated by using data obtained from available literature and

Table 1. Length of time of the infectious bovine rhinotracheitis (IBR) control programs in European countries

Country	Beginning	Ending
<i>IBR control programs carried out earlier, starting from the 1980s</i>		
Austria	1987	1999
Denmark	1984	1992
Finland	1978	1994
Switzerland	in the 1980s	1988
Norway	N.A.	1994
<i>IBR control programs carried out later, starting from the 1990s</i>		
Czech Republic	2005	2020
Germany	1997	2017
Italy ^{a,b}	in the 1990s	2017
Sweden	1994	1998
United Kingdom ^b	N.A.	2017
<i>IBR control programs still in progress since the 1990s</i>		
Belgium ^a	1991	Still in progress
France ^a	1996	Still in progress
Hungary	2002	Still in progress
Italy ^b	2015	Still in progress
Luxembourg ^a	2017	Still in progress
The Netherlands	1993	Still in progress
Slovakia	1996	Still in progress
Spain ^b	2004	Still in progress

N.A., not available.

^aIBR control program approved by European Commission (art. 9, Directive 432/64/EEC^c).

^bIBR control program limited to some territories.

^cCurrently repealed by Regulation 2016/429/EU

legislative sources. The first IBR outbreak in Europe was reported as a vesicular coital exanthema in Germany in the early 1900s, and its viral etiology was demonstrated in 1928. Genital signs of infection were the main form of the disease until the 1950s. At the same time, a more severe respiratory form of the disease, caused by the same virus, rapidly spread in America. This disease involving the upper respiratory tract is considered as the proven expression of IBR in cattle. IBR rapidly spread to Europe when American dairy cattle were imported to improve the milk production performance of European cattle (Muykens *et al.*, 2007). At present, BoHV-1 is still widespread (despite several territories that are officially free), although there are significant differences in herd-level prevalence; disease incidence between and within regions is depending, of course, on epidemiological conditions, but it is important to consider the geographical relationships and cattle management practices (Nettleton and Russel, 2017). To manage the disease, control schemes were first introduced in Europe in the late 1970s. Depending on the seroprevalence rate, eradication schemes are based on identification and removal of seropositive animals or employment of gE-deleted marker vaccines in infected herds (Raaperi *et al.*, 2014). In case of low seroprevalence, at herd level, as well as at territorial level, researching positive cases and slaughtering them could be a cheaper and more effective strategy; on the other hand, if viral circulation is reported

Table 2. IBR free-status in the whole country or some territories only (art. 10, Directive 432/64/EEC^a) in European countries subjected to UE approved or not UE approved control programs

Recognized in the whole country
Austria
Czech Republic
Denmark
Finland
Germany
Norway
Sweden
Switzerland
Limited to some territories
Italy ^b
United Kingdom ^c
Not recognized yet
Belgium
France
Luxembourg
The Netherlands

^aCurrently repealed by Regulation 2016/429/EU.

^bValle d'Aosta region; Bolzano province.

^cIsle of Jersey.

in most of the enrolled herds, vaccination strategy should be implemented. Consequently, to improve the IBR status of the territory, it is necessary to apply the proper strategy. These considerations influence both the efficacy and efficiency of the activities; the applied strategy is relevant in terms of cost/benefit ratio. The eradication process also differed in the period of measures application and in duration. Some countries began early with the eradication process, beginning from the 1980s, and the target was achieved in quite a short time. Other countries, although they implemented control measures in the 1990s, took a longer time to achieve eradication goals. In other cases, although an IBR control program has been in force for a long time, substantial results cannot be yet recorded. Finally some countries or parts of them implemented the eradication plans recently, so these plans are still in progress (Table 1). Therefore, in most cases, European countries obtained IBR-free status in their whole territory, and others in limited zones only (Table 2). Scandinavian countries, as well as Austria and Switzerland, were the first countries implementing and successfully concluding an IBR eradication program between the late 1970s and the early 1990s. The official approvals for both the eradication plan and the IBR-free status were obtained in a short period in the 1990s. Their low initial seroprevalence rate allowed them to adopt a 'test and slaughter' strategy. Germany, which showed an infection prevalence rate of 20%, implemented an eradication program based on the same strategy and obtained officially IBR-free status after 20 years (1997–2017). Belgium and the Netherlands started control programs for BoHV-1 infection in the early 1990s and, to date, have not received official IBR-free status; in these countries, a vaccination strategy has been employed since the initiation of the control programs. In Italy, a national eradication program became effective since 2015/2016, but involved only

specific beef breeds; nevertheless, some Italian regions and provinces implemented IBR control plans since the early 1990s and 2000s, and obtained official IBR-free status for their territories, such as the Valle d'Aosta region and Bolzano province. The Czech Republic started to control IBR in 2005, and obtained official approval of its eradication plan by the European Commission some years later (2008). In Hungary, a national eradication program has been in force since 2002. Slovakia implemented a compulsory control plan in 2006, whereas Spain implemented a voluntary one only in the region of Galicia, since 2004. Luxembourg adopted an eradication program and the European Commission approved it in 2017. In France, official authorities approved a compulsory eradication program in 2016.

Conclusions

All investigated countries managed IBR issues from the 1970s–1980s to date, by implementing various alternative strategies, successfully or not. Consequently, the European IBR status is diverse. This is an unfavorable condition for individual countries and the entire European territory. Therefore, as in the past, every State developed and implemented plans for disease management at the national level, the European legal and epidemiological background on IBR are not homogeneous. An opportunity to realize a harmonized approach for the management of IBR in Europe could be the new legislative tool, called the Animal Health Law (European Commission, 2016a) and, in general, the legal framework has been in force since 21 April 2021. Finally, a critical point involves data collection about IBR epidemiological surveillance in European countries. Currently, there is a lack of a European IBR informative system, and data collection on IBR management is fragmented even at a national level. If an efficient data sharing system be available, the analysis of surveillance data would support the progression of IBR control strategies.

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References

- Ackermann M and Wyler R (1984) The DNA of an IPV strain of bovid herpesvirus 1 in sacral ganglia during latency after intravaginal infection. *Veterinary Microbiology* **9**, 53–63.
- Ackermann M, Muller HK, Bruckner L and Kihm U (1990) Eradication of infectious bovine rhinotracheitis in Switzerland: review and prospects. *Veterinary Microbiology* **23**, 365–370.
- Ackermann M and Engels M (2006) Pro and contra IBR-eradication. *Veterinary Microbiology* **113**, 293–302.
- Beer M, König P, Schielke G and Trapp S (2003) Marker diagnostic for the eradication of bovine herpesvirus type 1: possibilities and limitations. *Berliner und Münchener tierärztliche Wochenschrift* **16**, 183–191.
- Bitsch V (1973) Infectious bovine rhinotracheitis virus infection in bulls, with special reference to preputial infection. *Applied Microbiology* **26**, 337–343.
- Bitsch V (1978) Persistence of infection with infectious bovine rhinotracheitis virus in Danish cattle herds. *Nordisk veterinærmedicin* **30**, 178–185.
- Brock J, Lange M, Tratalos JA, More SJ, Guelbenzu-Gonzalo M, Graham DA and Thulke HH (2021) A large-scale epidemiological model of BoHV-1 spread in the Irish cattle population to support decision-making in conformity with the European Animal Health Law. *Preventive Veterinary Medicine* **192**, 105375.
- De Wit JJ, Hage JJ, Brinkhof J and Westenbrink F (1998) A comparative study of serological tests for use in the bovine herpesvirus 1 eradication programme in the Netherlands. *Veterinary Microbiology* **61**, 153–163.
- Edwards S (1988) Changing trends in infectious bovine rhinotracheitis in Great Britain. *The Veterinary record* **123**, 614–618.
- European Commission (1964) Council Directive 64/432/EEC of 26 June 1964 on animal health problems affecting intra-community trade in bovine animals and swine. Available at <http://data.europa.eu/eli/dir/1964/432/2015-05-27> (Accessed 12 May 2020).
- European Commission (1988) Council Directive 88/407/EEC of 14 June 1988 laying down the animal health requirements applicable to intra-community trade in and imports of deep-frozen semen of domestic animals of the bovine species. Available at <http://data.europa.eu/eli/dir/1988/407/2011-11-01> (Accessed 12 May 2020).
- European Commission (1989) Council Directive 89/556/EEC of 25 September 1989 on animal health conditions governing intra-community trade in and importation from third countries of embryos of domestic animals of the bovine species. Available at <http://data.europa.eu/eli/dir/1989/556/2008-09-03> (Accessed 12 May 2020).
- European Commission (1993) Commission Decision 93/42/EEC of 21 December 1992 concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Denmark. Available at <http://data.europa.eu/eli/dec/1993/42/oj> (Accessed 12 May 2020).
- European Commission (1994) Commission Decision 94/962/EC of 28 December 1994 amending Commission Decision 93/42/EEC and concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Finland. Available at <http://data.europa.eu/eli/dec/1994/962/oj> (Accessed 12 May 2020).
- European Commission (1995a) Commission Decision 95/62/EC of 6 March 1995 approving the programme for the eradication of infectious bovine rhinotracheitis in Austria. Available at [http://data.europa.eu/eli/dec/1995/62\(1\)/oj](http://data.europa.eu/eli/dec/1995/62(1)/oj) (Accessed 12 May 2020).
- European Commission (1995b) Commission Decision 95/71/EC of 9 March 1995 approving the programme for the eradication of infectious bovine rhinotracheitis in Sweden. Available at [http://data.europa.eu/eli/dec/1995/71\(1\)/oj](http://data.europa.eu/eli/dec/1995/71(1)/oj) (Accessed 12 May 2020).
- European Commission (1995c) Commission Decision 95/109/EC of 29 March 1995 concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for certain parts of the territory of the community. Available at <http://data.europa.eu/eli/dec/1995/109/oj> (Accessed 12 May 2020).
- European Commission (1997) Commission Decision 97/250/EC of 25 March 1997 approving the programme for the eradication of infectious bovine rhinotracheitis in Austria. Available at <http://data.europa.eu/eli/dec/1997/250/oj> (Accessed 12 May 2020).
- European Commission (1998a) Commission Decision 98/362/EC of 19 May 1998 amending for the second time Commission Decision 93/42/EEC, concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Member States or regions of Member States free from the disease, in relation to Sweden and amending Commission Decision 95/109/EC. Available at <http://data.europa.eu/eli/dec/1998/362/ojb> (Accessed 12 May 2020).
- European Commission (1998b) Commission Decision 98/548/EC of 22 July 1998 amending for the third time Decision 93/42/EEC, concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Member States or Regions of Member States free from the disease, in relation to Austria and amending for the second time Decision 95/109/EC. Available at <http://data.europa.eu/eli/dec/1998/548/oj> (Accessed 12 May 2020).
- European Commission (1999) Commission Decision 99/579/EC of 28 July 1999 amending Decisions 93/42/EEC and 95/109/EC concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for certain parts of the territory of the community, and repealing Decision 97/250/EC. Available at <http://data.europa.eu/eli/dec/1999/579/oj> (Accessed 12 May 2020).
- European Commission (2004a) Commission Decision 2004/215/EC of 1 March 2004 implementing Council Directive 64/432/EEC as regards additional guarantees for intra-community trade in bovine animals relating

- to infectious bovine rhinotracheitis and the approval of the eradication programmes presented by certain Member States. Available at <http://data.europa.eu/eli/dec/2004/215/oj> (Accessed 12 May 2020).
- European Commission** (2004b) Commission Decision 2004/558/EC of 15 July 2004 implementing Council Directive 64/432/EEC as regards additional guarantees for intra-community trade in bovine animals relating to infectious bovine rhinotracheitis and the approval of the eradication programmes presented by certain Member States. Available at <http://data.europa.eu/eli/dec/2004/558/2019-01-14> (Accessed 12 May 2020).
- European Commission** (2007) Commission Decision 2007/584/EC of 21 August 2007 amending Decision 2004/558/EC implementing Council Directive 64/432/EEC as regards additional guarantees for intra-community trade in bovine animals relating to infectious bovine rhinotracheitis and the approval of the eradication programmes presented by certain Member States. Available at <http://data.europa.eu/eli/dec/2007/584/oj> (Accessed 12 May 2020).
- European Commission** (2008) Commission Decision 2008/233/EC of 17 March 2008 amending Decision 2004/558/EC implementing Council Directive 64/432/EEC as regards additional guarantees for intra-community trade in bovine animals relating to infectious bovine rhinotracheitis and the approval of the eradication programme presented by certain Member States. Available at <http://data.europa.eu/eli/dec/2008/233/oj> (Accessed 12 May 2020).
- European Commission** (2010) Commission Decision 2010/433/EU of 5 August 2010 amending Decision 2004/558/EC implementing Council Directive 64/432/EEC as regards additional guarantees for intra-community trade in bovine animals relating to infectious bovine rhinotracheitis. Available at <http://data.europa.eu/eli/dec/2010/433/oj> (Accessed 12 May 2020).
- European Commission** (2011) Commission Implementing Decision 2011/674/EU of 12 October 2011 amending Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of certain administrative regions in Germany. Available at http://data.europa.eu/eli/dec_impl/2011/674/oj (Accessed 12 May 2020).
- European Commission** (2014) Commission Implementing Decision 2014/703/EU of 8 October 2014 amending Annexes I and II to Decision 2004/558/EC as regards the approval of a control programme for eradicating infectious bovine rhinotracheitis in Belgium and the infectious bovine rhinotracheitis-free status of the Federal State of Thuringia in Germany. Available at http://data.europa.eu/eli/dec_impl/2014/703/oj (Accessed 12 May 2020).
- European Commission** (2015a) Commission Implementing Decision (EU) 2015/250/EU of 13 February 2015 amending Annexes I and II to Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of the Federal States of Saxony, Saxony-Anhalt, Brandenburg, Berlin and Mecklenburg-Western Pomerania in Germany. Available at http://data.europa.eu/eli/dec_impl/2015/250/oj (Accessed 12 May 2020).
- European Commission** (2015b) Commission Implementing Decision 2015/1765/EU of 30 September 2015 amending Annexes I and II to Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of the Federal State of Baden-Württemberg of Germany and of the region Valle d'Aosta of Italy. Available at http://data.europa.eu/eli/dec_impl/2015/1765/oj (Accessed 12 May 2020).
- European Commission** (2015c) Commission Implementing Decision 2015/2278/EU of 4 December 2015 amending Annexes I and II to Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of the Federal States of Bremen, Hesse and Lower Saxony of Germany. Available at http://data.europa.eu/eli/dec_impl/2015/2278/oj (Accessed 12 May 2020).
- European Commission** (2016a) Regulation 2016/429/EU of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'). Available at <http://data.europa.eu/eli/reg/2016/429/2019-12-14> (Accessed 12 May 2020).
- European Commission** (2016b) Commission Implementing Decision 2016/1101/EU of 5 July 2016 amending Annexes I and II to Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of the Federal States of Rhineland-Palatinate, Saarland and the Regierungsbezirke Arnsberg, Detmold and Münster in Germany. Available at http://data.europa.eu/eli/dec_impl/2016/1101/oj (Accessed 12 May 2020).
- European Commission** (2017a) Commission Implementing Decision (EU) 2017/486 of 17 March 2017 amending Annexes I and II to Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of Luxembourg, of the Federal States Hamburg and Schleswig-Holstein of Germany and of Jersey, and amending Annex II to Decision 2008/185/EC as regards the Aujeszky's disease-free status of the Friuli Venezia Giulia region of Italy. Available at http://data.europa.eu/eli/dec_impl/2017/486/oj (Accessed 12 May 2020).
- European Commission** (2017b) Commission Implementing Decision (EU) 2017/888 of 22 May 2017 amending Decision 2003/467/EC as regards the official tuberculosis-free status of the region of Umbria of Italy and of the enzootic-bovine-leukosis-free status of Poland, amending Decision 2004/558/EC as regards the infectious bovine rhinotracheitis-free status of Germany, and amending Decision 2008/185/EC as regards the Aujeszky's disease-free status of certain regions of Poland and the approval of the eradication programme for Aujeszky's disease for the region of Veneto of Italy. Available at http://data.europa.eu/eli/dec_impl/2017/888/oj (Accessed 12 May 2020).
- European Commission** (2018a) Commission Delegated Regulation (EU) 2018/1629 of 25 July 2018 amending the list of diseases set out in Annex II to Regulation (EU) 2016/429 of the European Parliament and of the Council on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'). Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1629&rid=1> (Accessed 23 February 2021).
- European Commission** (2018b) Commission Implementing Regulation (EU) 2018/1882 of 3 December 2018 on the application of certain disease prevention and control rules to categories of listed diseases and establishing a list of species and groups of species posing a considerable risk for the spread of those listed diseases. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1882&rid=1> (Accessed 23 February 2021).
- European Commission** (2020a) Commission Implementing Decision (EU) 2020/1663 of 6 November 2020 amending Annexes I and II to Decision 2004/558/EC as regards the disease-free status of Czechia and the approval of the eradication programme in several regions of France regarding infectious bovine rhinotracheitis. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020D1663&rid=1> (Accessed 12 November 2020).
- European Commission** (2020b) Commission Implementing Regulation (EU) 2020/2002 of 7 December 2020 laying down rules for the application of Regulation (EU) 2016/429 of the European Parliament and of the Council with regard to Union notification and Union reporting of listed diseases, to formats and procedures for submission and reporting of Union surveillance programmes and of eradication programmes and for application for recognition of disease-free status, and to the computerised information system. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R2002&rid=1> (Accessed 23 February 2021).
- European Commission** (2020c) Commission Delegated Regulation (EU) 2020/689 of 17 December 2019 supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council as regards rules for surveillance, eradication programmes, and disease-free status for certain listed and emerging diseases. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02020R0689-20210421&qid=1626178213119&from=EN> (Accessed 12 July 2021).
- European Commission** (2020d) Commission Delegated Regulation (EU) 2020/686 of 17 December 2019 supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council as regards the approval of germinal product establishments and the traceability and animal health requirements for movements within the Union of germinal products of certain kept terrestrial animals. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0686&qid=1626178264987&from=EN> (Accessed 12 July 2021).
- European Commission** (2020e) Commission Delegated Regulation (EU) 2020/688 of 17 December 2019 supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council, as regards animal health requirements for movements within the Union of terrestrial animals and hatching eggs. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0688&qid=1626178339320&from=EN> (Accessed 12 July 2021).

- European Commission** (2021) Commission Implementing Regulation (EU) 2021/620 of 15 April 2021 laying down rules for the application of Regulation (EU) 2016/429 of the European Parliament and of the Council as regards the approval of the disease-free and non-vaccination status of certain Member States or zones or compartments thereof as regards certain listed diseases and the approval of eradication programmes for those listed diseases. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R0620&qid=1626083832114&from=EN> (Accessed 12 July 2021).
- European Free Trade Association 'EFTA' Surveillance Authority** (1994a) Decision 20/94/COL of 30 March 1994 concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Finland. Available at [http://data.europa.eu/eli/dec/1994/20\(2\)/oj](http://data.europa.eu/eli/dec/1994/20(2)/oj) (Accessed 12 May 2020).
- European Free Trade Association 'EFTA' Surveillance Authority** (1994b) Decision 73/94/COL of 27 June 1994 concerning the approval of an eradication programme for infectious bovine rhinotracheitis in Sweden and laying down additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Sweden. Available at [http://data.europa.eu/eli/dec/1994/73\(2\)/oj](http://data.europa.eu/eli/dec/1994/73(2)/oj) (Accessed 12 May 2020).
- European Free Trade Association 'EFTA' Surveillance Authority** (1994c) Decision 74/94/COL of 27 June 1994 concerning additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Norway. Available at [http://data.europa.eu/eli/dec/1994/74\(2\)/oj](http://data.europa.eu/eli/dec/1994/74(2)/oj) (Accessed 12 May 2020).
- European Free Trade Association 'EFTA' Surveillance Authority** (1994d) Decision 76/94/COL of 27 June 1994 concerning the approval of an eradication programme for infectious bovine rhinotracheitis in Austria and laying down additional guarantees relating to infectious bovine rhinotracheitis for bovines destined for Austria. Available at [http://data.europa.eu/eli/dec/1994/76\(2\)/oj](http://data.europa.eu/eli/dec/1994/76(2)/oj) (Accessed 12 May 2020).
- European Free Trade Association 'EFTA' Surveillance Authority** (2010) Decision 159/10/COL of 21 April 2010 concerning additional guarantees for Norway relating to infectious bovine rhinotracheitis. Available at <http://data.europa.eu/eli/dec/2010/159/oj> (Accessed 12 May 2020).
- Graat EA, De Jong MC, Frankena K and Franken P** (2001) Modelling the effect of surveillance programmes on spread of bovine herpesvirus 1 between certified cattle herds. *Veterinary Microbiology* **79**, 193–208.
- Graham DA** (2013) Bovine herpes virus-1 (BoHV-1) in cattle- a review with emphasis on reproductive impacts and the emergence of infection in Ireland and the United Kingdom. *Irish veterinary journal* **66**, 15–25.
- Kendrick JW, York CJ and McKercher DG** (1956) A controlled field trial of a vaccine for infectious bovine rhinotracheitis. *Proceedings of 60th annual meeting of the United States Livestock Sanitary Association* **60**, 155–158.
- Kofer J, Wagner P and Deutz A** (1999) BHV-1 infections in Styria (Austria) caused by intra-community trade. *Deutsche tierärztliche Wochenschrift* **106**, 231–233.
- Madin SH, Mckercher DG and York CJ** (1956) Isolation of infectious bovine rhinotracheitis virus. *Science (New York, N.Y.)* **124**, 721–722.
- Makoschey B, Zehle H-H, Bussacchini M, Valla G, Pálfi V and Földi J** (2007) Efficacy of a live bovine herpesvirus type 1 marker vaccine under field conditions in three countries. *Veterinary Record* **161**, 295–298.
- Mandelik R, Bires J, Ozsvári L, Hodnik JJ and Vilcek S** (2021) Infectious bovine rhinotracheitis control program in Slovakia. *Frontiers in Veterinary Science* **8**, 675521.
- Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. Infectious Bovine Rhinotracheitis** (2018) Available online at https://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/3.04.11_IBR_IPV.pdf (Accessed 12 May 2020).
- Maresca C, Scoccia E, Dettori A, Felici A, Guarcini R, Petrini S, Quaglia A and Filippini G** (2018) National surveillance plan for infectious bovine rhinotracheitis (IBR) in autochthonous Italian cattle breeds: results of first year of activity. *Veterinary Microbiology* **219**, 150–153.
- Mars MH, De Jong MC, Franken P and Van Oirschot JT** (2001) Efficacy of a live glycoprotein E-negative bovine herpesvirus 1 vaccine in cattle in the field. *Vaccine* **19**, 1924–1930.
- Minister for Agriculture and Food** (2002) Diseases of Animal Act 1966 (control on animal and poultry vaccines) order 2002. Available at <http://www.irishstatutebook.ie/eli/2002/si/528/made/en/print#> (Accessed 12 May 2020).
- Ministero delle Politiche Agricole Alimentari e Forestali (MIPAAF)** (2015) Decreto Dirigenziale prot. n. 11100 del 01 giugno 2015. Piano di gestione degli allevamenti dei bovini iscritti ai libri genealogici delle 5 razze italiane da carne finalizzato al risanamento dal virus responsabile della rinotracheite infettiva del bovino (IBR). Available at <https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/8722> (Accessed 12 May 2020).
- Ministero delle Politiche Agricole Alimentari e Forestali (MIPAAF)** (2016) Decreto Ministeriale n. 31679 del 23 dicembre 2016. Piano di gestione degli allevamenti dei bovini iscritti al libro genealogico della razza Piemontese finalizzato al risanamento dal virus responsabile della rinotracheite infettiva del bovino (IBR). Available at <https://www.anaborapi.it/images/media/pdf/appuntamenti/2017/piano%20IBR.pdf> (Accessed 12 May 2020).
- Moretti B, Orfei Z, Mondino G and Persechino A** (1964) Isolation of the infectious bovine rhinotracheitis (IBR) virus in Italy. Preliminary note. *Nuovi annali d'igiene e microbiologia* **15**, 18–22.
- Muykens B, Thiry J, Kirten P, Schynts F and Thiry E** (2007) Bovine herpesvirus 1 infection and infectious bovine rhinotracheitis. *Veterinary Research* **38**, 181–209.
- Nandi S, Kumar M, Manohar M and Chauhan S** (2009) Bovine herpes virus infections in cattle. *Animal Health Research Review* **19**, 85–98.
- Nettleton P and Russel G** (2017) Update on infectious bovine rhinotracheitis. *In Practice* **39**, 255–272.
- Noordegraaf AV, Jalvingh AW, De Jong MCM, Franken P and Dijkhuizen AA** (2000) Evaluating control strategies for outbreaks in BHV1-free areas using stochastic and spatial simulation. *Preventive Veterinary Medicine* **44**, 21–42.
- Nuotio L, Neuvonen E and Hyytiäinen M** (2007) Epidemiology and eradication of infectious bovine rhinotracheitis/infectious pustular vulvovaginitis (IBR/IPV) virus in Finland. *Acta Veterinaria Scandinavica* **49**, 3–8.
- Nylin B, Madsen KG and Rensholt L** (1998) Reintroduction of bovine herpes virus type 1 into Danish cattle herds during the period 1991–1995: a review of the investigations in the infected herds. *Acta Veterinaria Scandinavica* **39**, 401–413.
- Nylin B, Stroger U and Ronsholt L** (2000) A retrospective evaluation of a bovine herpesvirus-1 (BHV-1) antibody ELISA on bulk-tank milk samples for classification of the BHV-1 status of Danish dairy herds. *Preventive Veterinary Medicine* **47**, 91–105.
- Paisley LG, Tharaldsen J and Jarp J** (2001) A retrospective analysis of the infectious bovine rhinotracheitis (bovine herpes virus-1) surveillance program in Norway using Monte Carlo simulation models. *Preventive Veterinary Medicine* **50**, 109–125.
- Raaperi K, Alekseev A, Orro T and Viltrop A** (2012) Dynamics of bovine herpesvirus type 1 infection in Estonian dairy herds with and without a control programme. *The Veterinary Record* **171**, 99.
- Raaperi K, Orro T and Viltrop A** (2014) Epidemiology and control of bovine herpesvirus 1 infection in Europe. *The Veterinary Journal* **201**, 246–256.
- Republic of Austria** (1989) Bundesgesetz vom 12. Dezember 1989 zur Bekämpfung der Infektiösen Bovinen Rhinotracheitis und der Infektiösen Pustulösen Vulvovaginitis (IBR/IPV- Gesetz). BGBl. Nr. 636/1989, idgF.
- Roch FF and Conrady B** (2021) Overview of mitigation programs for non-EU regulated cattle diseases in Austria. *Frontiers in Veterinary Science* **8**, 689244.
- Ruffo G, Beghetto M, La Greca E and Fossati P** (2017a) Rinotracheite infettiva bovina (IBR): una malattia non soggetta a obbligo di denuncia in Italia e il piano di controllo in Regione Veneto, parte 1. Rassegna di Diritto, Legislazione e Medicina Legale Veterinaria, Anno XVI- Monografia n.1/2017.
- Santman-Berends IMGA, Mars MH, Waldeck HWF, Van Duijn L, Wever P, Van den Broek KWH and Van Schaik G** (2018) Quantification of the probability of reintroduction of IBR in the Netherlands through cattle imports. *Preventive Veterinary Medicine* **150**, 168–175.
- Sayers RG, Byrne N, O'Doherty E and Arkins S** (2015) Prevalence of exposure to bovine viral diarrhoea virus (BVDV) and bovine herpesvirus-1 (BoHV-1) in Irish dairy herds. *Research in Veterinary Science* **100**, 21–30.
- Simon, AJ** (2004) A practical approach to the future control of IBR in Ireland using marker vaccines. *Proceedings of the Cattle Association of Veterinary Ireland Conference, October*.

- Straub OC** (1975) Infectious bovine rhinotracheitis virus. History and recent developments. *Developments in Biological Standardization* **28**, 530–533.
- Swiss Confederation** (1995) Ordinanza sulle epizoozie (OFE) del 27 giugno 1995. Available at <https://www.admin.ch/opc/it/classified-compilation/19950206/index.html> (Accessed 12 May 2020).
- Swiss Confederation** (1999) Accordo tra la Confederazione Svizzera e la Comunità Europea sul commercio di prodotti agricoli del 21 giugno 1999. Available at <https://www.admin.ch/opc/it/classified-compilation/19994645/index.html> (Accessed 12 May 2020).
- Swiss Confederation** (2018) Rapporto sulla sorveglianza delle epizoozie, dati 2017. Available at https://webcache.googleusercontent.com/search?q=cache:m-DpMo2_h4UJ:https://www.blv.admin.ch/dam/blv/it/dokumente/tiere/publikationen-und-forschung/statistik-und-berichte/bericht-ueberwachung-tierseuchen-2017.pdf.download.pdf/Bericht_zur_%25C3%259Cberwachung_von_Tierseuchen_2017_IT.PDF.pdf+%&cd=1&hl=it&ct=clnk&gl=it&client=firefox-b-ab (Accessed 12 May 2020).
- Tamba M, Pallante I, Petrini S, Feliziani F, Iscaro C, Arrigoni N, Di Sabatino D, Barberio A, Cibir V, Santi A, Ianniello M, Ruocco L and Pozzato N** (2021) Overview of control programs for EU non-regulated cattle diseases in Italy. *Frontiers in Veterinary Science* **8**, 665607.
- Tanyi J and Varga J** (1992) Guidelines for the eradication of infectious bovine rhinotracheitis in Hungary. *Acta Veterinaria Hungarica* **40**, 165–169.
- Valas S, Bremaud I, Stourm S, Croise B, Meneteau S, Ngwa-Mbot D and Tabouret M** (2019) Improvement of eradication program for infectious bovine rhinotracheitis in France inferred by serological monitoring of singleton reactors in certified BoHV1-free herds. *Preventive Veterinary Medicine* **171**, 104743.
- Van Oirschot JT, Kaashoek MJ and Rijsewijk FA** (1996) Advances in the development of bovine herpesvirus 1 vaccines. *Veterinary Microbiology* **53**, 43–54.
- Van Schaik G, Dijkhuizen AA, Huirne RBM, Schukken YH, Nielen M and Hage HJ** (1998) Risk factors for existence of bovine herpes virus 1 antibodies on non vaccinating Dutch dairy farms. *Preventive Veterinary Medicine* **34**, 125–136.
- Veterinary Investigation Diagnosis Analysis ‘VIDA’** (2015) Annual report on data recorded by APHA and Scotland’s Rural College on animal and bird diagnostic submissions in Great Britain. Available at <https://www.gov.uk/government/publications/veterinary-investigation-diagnosis-analysis-vida-report-2015> (Accessed 12 May 2020).
- Villaamil FJ, Arnaiz I, Allepuz A, Molins M, Lazaro M, Benavides B, Moya SJ, Fabrega JC, Yus E and Dieguez FJ** (2020) A survey of biosecurity measures and serological status for bovine viral diarrhoea virus and bovine herpesvirus1 on dairy cattle farms in north-west and north-east Spain. *Veterinary Record Open* **7**, e000399.
- Vonk Noordegraaf A, Buijtel JA, Dijkhuizen AA, Franken P, Stegeman JA and Verhooff J** (1998) An epidemiological and economic simulation model to evaluate the spread and control of infectious bovine rhinotracheitis in The Netherlands. *Preventive Veterinary Medicine* **36**, 219–238.
- Vonk Noordegraaf A, Labrovic A, Frankena K, Pfeiffer DU and Nielen M** (2004) Simulated hazards of loosing infection-free status in a Dutch BHV1 model. *Preventive Veterinary Medicine* **62**, 51–58.
- Wentink GH, Van Oirschot JT and Verhooff J** (1993) Risk of infection with bovine herpes virus 1 (BHV1): a review. *The Veterinary Quarterly* **15**, 30–33.
- Wergifosse B, Lemaire M, Pastoret PP and Thiry E** (1997) Etablissement d’un plan volontaire de controle de la rhinotracheite infectieuse bovine en Region Wallonne de Belgique. *Annales de Médecine Vétérinaire* **141**, 185–196.
- Winkler MT, Doster A and Jones C** (2000) Persistence and reactivation of bovine herpesvirus 1 in the tonsils of latently infected calves. *Journal of Virology* **74**, 5337–5346.