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IMPACT OF THE COVID-19 PANDEMIC ON EMBRYO TRANSFER ACTIVITIES IN EUROPE

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ABSTRACT. This review highlights to what extent the embryo transfer (ET) activity in Europe was affected by the COVID-19 pandemic. The ET represents a procedure of modern reproductive biotechnologies that is increasingly applied in farms animals. Commercial ET is applied to cattle and, albeit to a lesser extent, to other species. For this study, official data reported by each country to the European (AETE) and international (IETS) forums, regarding ET activities, were accessed. Each country has an official rapporteur, but the procedures are not mandatory. The reported data included the total number of ET sessions, the type of embryos obtained *in vivo* derived (IVD) or *in vitro* produced (IVP), the collection rate of oocytes and embryos and transferable embryos produced both in cattle and other species. For comparison, the data of two similar pre-pandemic (2017 and 2018) and pandemic (2019 and 2020) periods were analysed. The pandemic period (2019) started with a record decrease in all categories of ET, most likely because of less reports by veterinaries since reporting took place in May 2020, already pandemic time Europe, indicating a false negative decrease in Europe, the total ET activities reported decreased by 31.59%. In 2019, the *in vivo* ET procedures in cattle decreased by 26,421 sessions compared to 2018 (approximately 20%). Surprisingly, during the pandemic, *in vivo* ET in equines increased by almost 40%.

Keywords: covid; embryo transfer; IVD; IVP; pandemic.

INTRODUCTION

General presentation of embryo technologies

Reproductive biotechnologies (RB) are classified according to the generation and time of appearance. The first biotechnology is artificial insemination

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(AI), and the second is embryo transfer (ET) *in vivo* through multiple ovulations. Embryo transfer is a reproductive biotechnology with a major impact on the animal husbandry industry as commercial application enables a more efficient production of farm animals (Toba *et al.*, 2021).

First-generation reproductive biotechnique (AI) is based on the use of male genetics but produces slow genetic progress and occurs over time. With the evolution of science and the emergence of modern biotechnologies (after the 1970s) with the following generations (ET, IVF), solid and functional bases have been developed regarding the practical application of ET. Generally, ET aims to perpetuate the genetics of the females with genetic merit. The development of the capacity to preserve and transport embryos at a distance and in a limited time made ET an even more wanted technology. Its advantages are classified as genetic, sanitary-veterinary, economic and zootechnical (Emoke and Cenariu, 2020).

The use of ET as a reproductive biotechnology continues to increase globally, even in countries without a tradition of ET. Embryo Transfer as biotechnology offers a means by which offspring multiply quickly and with the same genetic origin, and practitioners and veterinarians have developed it for commercial use. Thus, a transfer of techniques from the laboratory to farms took place. For a technical and scientific coordination of practitioners, the International Embryo Transfer Society (IETS - USA) was established (IETS, 2023). Today, the majority of countries in Europe have ET associations, where ET activities are reported to support and develop biotechnology ET and other embryo technologies (e.g., AETE, SIET, AET-d, AETF, ARET and other regional biotechnology associations) (AETE, 2023; Ciornei, 2021a).

Currently, ET is routinely used in cattle to produce bulls with controlled genetics. New genomic testing techniques are increasingly used for the selection of embryo donors, and this is becoming decisive for the selection of donors used in ET. Both ET and AI are the basis of reproductive biotechnology and genetic progress in the farm industry (Ciornei, 2021a).

In recent years, due to the explosive technological development and research and innovation in this direction, the production of embryos has been improved, the materials and consumables have become cheaper and the equipment more efficient. All this makes the cost of embryo production more efficient and results in higher embryo quality.

Reproductive technologies have been developed to overcome the limitations imposed by the biology of reproduction or the characteristics of gametes and the embryo. Lately, biotechnology has been based on increasing productivity and resistance to disease. Modern reproductive technologies have opened many ways to study, treat and manipulate some mechanisms involved in reproduction, thus improving the reproductive performance of various domestic and wild species (Mircu *et al.*, 2020).

The ET technology has been mainly applied in bovine species, but currently, there is a growing interest in using this technology in other species such as sheep and horses. These

breeding biotechnologies are constantly developing and improving, arousing real interest from farmers both in the livestock and pet sectors.

LITERATURE REVIEW

COVID-19 - the role of domestic animals in transmission and the associated risks in the context of reproductive technology

In general, animal infections with viruses from the coronaviral family are common, generally in pets, less often in farm animals (FAO, 2021).

Veterinarians and veterinary technicians involved in the consultation and treatment of animals frequently come into contact with such animals and their secretions and milk/meat.

Because of the suspected animal origin of SARS-CoV-2, it is important to review as thoroughly as possible the available literature on the role of animals in SARS-CoV-2 infection and transmission. In the special case of animal reproduction supervision and assistance, it is necessary to evaluate the potential role of the reproductive material (semen, oocytes, embryos) in the transmission of the pathogen (Ciornei, 2021b).

Most organisations in the veterinary medical field highlight the importance of veterinary activities in the pandemic and post-pandemic periods, important for the supervision of animal and human health, by ensuring quality in the field of food safety, the prevention of communicable diseases and actions in emergency situations.

The evolution of Covid-19 infections began in December 2019, and Covid-19 was declared an international pandemic by the World Health Organization (WHO, 2021) in March 2020 (interactive timeline). The pandemic was not only a major global health and social crisis, but it has and has had a huge impact on the global economy. In this context, a negative influence on all areas is to be expected, producing a domino effect. As far as the international embryo production industry is concerned, effects of the pandemic are to be expected.

However, the statistics of 2020 show that the overall activity of ET has been inconstant, increasing or decreasing depending on the continent, country and region, compared to that presented in 2019.

It can be said that the pandemic has had an uneven effect on the embryonic industry, and its influence should therefore be evaluated over a longer period of time. The major problem in the embryonic industry would be the disorganisation and the delays produced in the flow of securing equipment and consumables from producers and distributors, leading to an in the prices of goods, including those of animal origin (FAO, 2021).

There was and is limited evidence that domestic pets (dogs, cats and chickens) and farm animals (cattle, horses, pigs, minks) can be infected and transmit the virus to each other (Ciornei, 2021a) and to humans. Few experimental studies on ruminants showed that calves after calving induced a low level of infection, but it was not transmissible to other calves (Ciornei, 2021a).

Another study showed that an asymptomatic infection can occur in white-tailed deer with transmission to contact deer (Palmer *et al.*, 2021). Another experimental study involving domestic pigs reported low-level infection but no contact transmission to the population (Pickering *et al.*, 2021).

Therefore, veterinary medicine is in a complex position: on the one hand, its priority is to investigate the possible source of animal infection, but on the other hand, it has the professional and deontological duty to defend the animals, frequently unjustly incriminated. In this context, it is important to remember that Covid-19 is a syndrome and not a specific disease, and clinical confusion may occur during diagnostic investigations (Ciornei, 2021b).

Viral infection and transmission during assisted animal reproduction techniques

Currently, in the specialised literature, it seems that there is no information that accurately and specifically describes the role of assisted reproduction techniques (ART) in the veterinary field in the transmission of SARS-CoV-2 in animal germplasm. What we currently know is that the SARS-CoV-2 virus can be present in the secretions of the upper respiratory tract (nasal, laryngeal and bronchial secretions) and the excretions of the digestive tract (faeces and urine) (Kim *et al.*, 2020; OIE, 2020).

Currently, there is no evidence of the transmission of SARS-CoV-2 through sexual, venereal, sperm, embryo or placental transmission in animals (Viana, 2019, 2020).

METHODS AND ANALYSES

Data collection of commercial embryo transfer activity

The necessary information for this study was obtained from the network of professional associations that are regionally affiliated and internationally subordinated to the IETS. In this international organization, there is the Data Collection Committee (DRC), which is coordinated and directed by the IETS, which is responsible for collecting data as objectively as possible and deals with the centralisation and distribution of statistics regarding the application of ET and the production of embryos in animals for commercial purposes. Data are collected yearly, for the previous year's activity, by local reporters until May; the local reporters transmit the centralisation until the middle of the current year (usually the end of May) to the regional organisations. These organisations centralise the information by region/continent and transmit it through the DRC to the IETS. In December, IETS publication of the Embryo Technology Newsletter, the DRC publishes the statistics for the previous year. Embryo technology activities can also be reported individually by practitioners directly to the IETS after prior registration and approval. Thus, data from each country are either reported by a local data collector or individually (IETS, 2021).

Regarding the member countries of the European Union, the data are sent by a continental/regional collector represented by the Technological Association of Embryos in Europe (AETE, 2023; Viana, 2018).

RESULTS AND DISCUSSION

Data of ET activity in Europe in the pre/-pandemic period (2017–2020)

The ET activities reported at the European level are centralised in two series grouped in 2 years, namely 2 years of the evolution of the pandemic and 2 years before it. The purpose of this study is to understand if and, if yes, in which manner the evolution of the COVID-19 pandemic has influenced ET procedures in Europe.

The total ET sessions reported in Europe in the period from 2017–2022 equalled 584,006 (*Figure 1)*. In the pre-pandemic period (years 2017–2018), that number was 346,781, whereas in pandemic years (2019–2020), 237,225 sessions were reported, indicating a decreased of 31.59% (*Figure 2*).

Based on the difference of 109,556, this is almost a third of the number of ETs made in the pre-pandemic period. With the start of the pandemic (2019), in 2020, a record decrease in all categories of ET was observed. The ET procedures in cattle accounted for almost 90% of the total procedures (*Figure 3*).

For ET in cattle, a significant difference can be observed between the two studied periods, with a decrease of over 30% from pre-pandemic to pandemic periods.

Regarding the negative influence of the pandemic, it started in 2019, when the number of ET procedures *in vivo* in cattle decreased by 26,421 compared to 2018 (by approximately 20%).

This decrease can be explained by the low reporting of ET activities in 2020 for 2019, but also by the social psychosis that started in 2019 and led to the limitation of interactions.

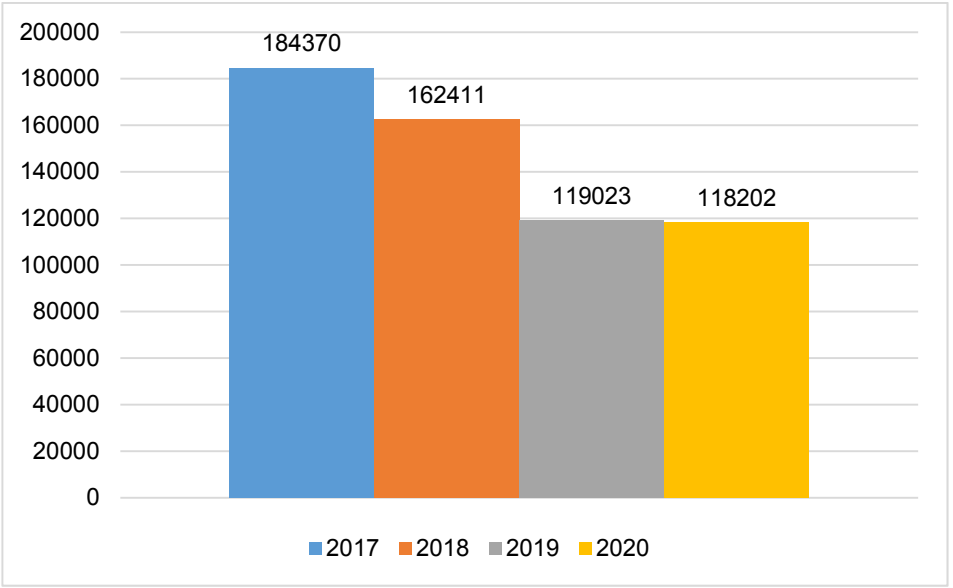

Figure 1 – Embryo transfer as a total number of procedures distributed over the 4 years (2017–2020), two pre-pandemic and two pandemic years

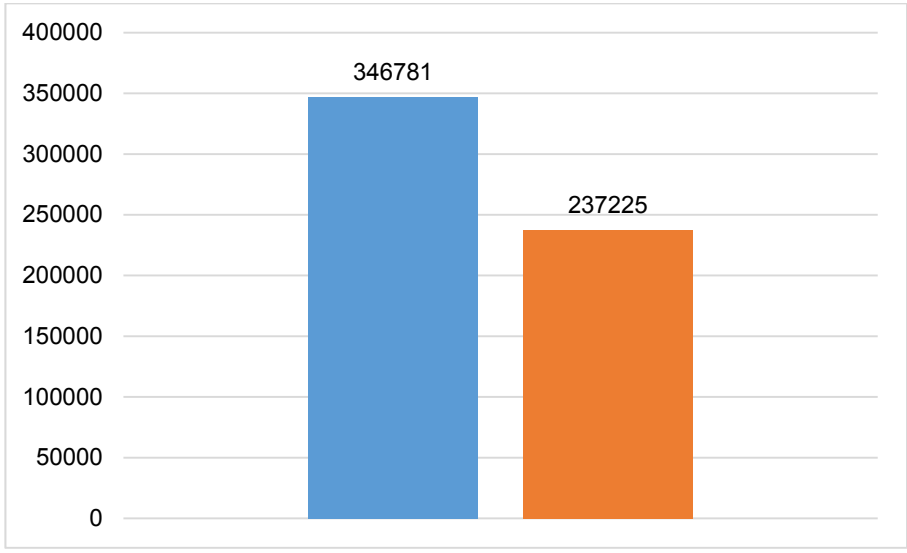

Figure 2 – Graphic representation of the difference between pandemic and ante-pandemic years regarding the total ET sessions in Europe

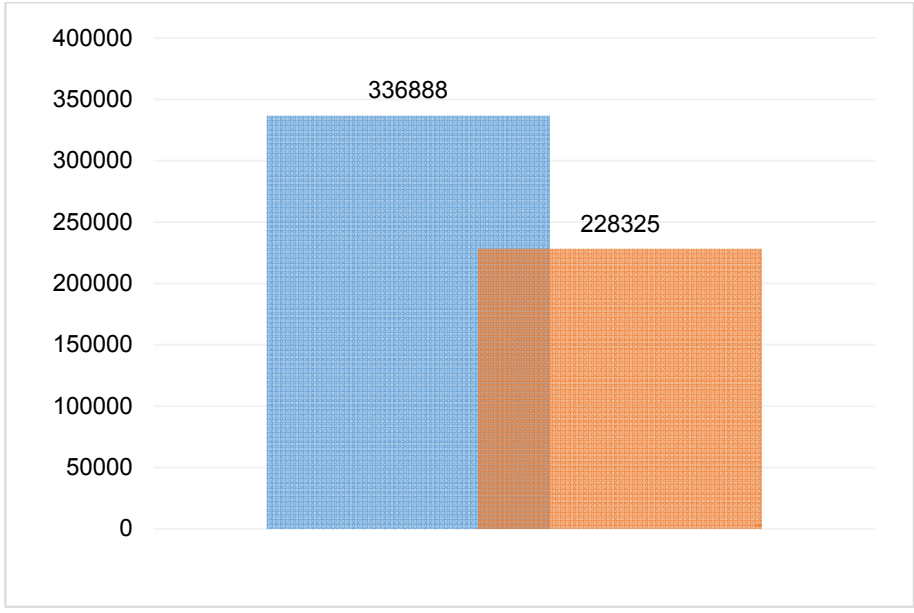

Figure 3 – Embryo transfer evaluated in cattle during the pre-pandemic (2017–2018) and pandemic period (2019–2020)

Drastic declines were also seen in equine and sheep ET procedures (included in the category "other species"). In the case of total sessions of ET in other species, the percentage by which the number of ET sessions decreased was approximately 10% (*Figure 4*).

The last year of the report (2022) coincides with the peak of the pandemic, the year in which the fewest ET sessions were recorded.

The *in vitro* ET in sessions in cattle decreased by almost 7,000 compared to the previous year (2019).

Bovine *in vivo* embryo production

Notably, for the Ukraine and the United Kingdom, there was no information about ET after 2019, which was also the case for Luxembourg and Poland. For Israel and Ireland, there was no information for 2020, and we therefore assume that ET was stopped due to the Covid pandemic. In 2017, 143,461 viable embryos were collected; this number was 144,117 in 2018, 124,986 in 2019 and 120,982 in 2020 (*Table 1* and *Table 2*).

Figure 5 shows the evolution of viable embryo collection in Europe between 2017 and 2020.

Table 1 – Bovine *in vivo* embryo production in 2017 and 2018

Country	2017			2018		
	Collections	Viable embryos	Embryos/collections	Collections	Viable embryos	Embryos/collections
Austria	271	2,014	7	364	2,626	7
Belgium	1,160	5,973	5	1,004	4,741	5
Denmark	759	4,785	6	770	4,553	6
Finland	310	1,949	6	489	2,718	6
France	6,729	35,277	5	6,886	36,769	5
Germany	3,412	22,882	7	3,630	23,599	7
Hungary	60	371	6	60	371	6
Ireland	785	4,328	5	664	3,904	6
Israel	60	212	3	43	162	4
Italy	2,500	19,883	8	2,582	20,501	8
Latvia	6	0	0	11	43	4
Lithuania	4	23	6	0	0	0
Luxembourg	212	1,151	5			
The Netherlands	2493	21,910	9	2,751	15,675	6
Norway	60	370	6	98	640	7
Poland	226	1,177	5	269	1,493	6
Portugal	102	510	5	120	390	3
Russian Federation	1,855	12,832	7	2,085	14,098	7
Romania	0	0	0	9	40	4
Serbia	6	25	4	5	14	3
Slovenia	11	33	3	14	26	3
Spain	551	2,930	5	763	4,628	6
Sweden	130	564	4	130	564	4
Switzerland	543	3,911	7	376	2,196	6
Ukraine	10	21	2	30	334	11
United Kingdom	61	327	5	243	1,281	5

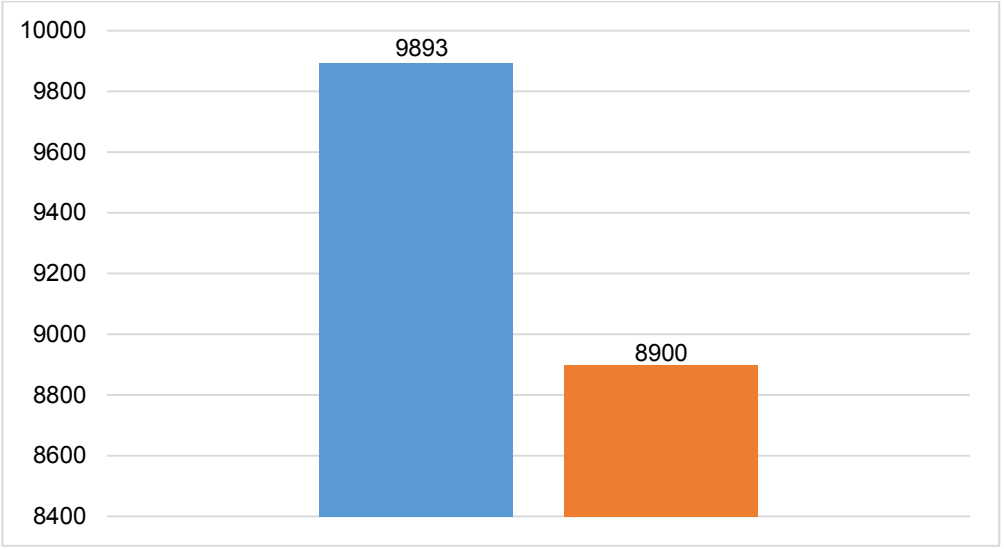

Figure 4 – Embryo transfer in other species during the pre-pandemic and pandemic periods

Table 2 – Bovine *in vivo* embryo production in 2019 and 2020

Country	2019			2020		
	Collec-tions	Viable embryos	Embryos/co-llections	Collec-tions	Viable embryos	Embryos/co-llections
Austria	425	3,090	7	531	3,600	7
Belgium	754	3,596	5	789	3,656	5
Denmark	787	5,011	6	841	5,555	7
Finland	409	2,367	6	435	2,971	7
France	6,029	36,823	6	6,142	37,505	6
Germany	2,325	21,783	6	3,602	24,641	7
Hungary	5	21	4	407	912	2
Ireland	610	3,321	5			
Israel	26	94	5			
Italy	2,735	19,404	7	2,576	18,249	7
Latvia	14	59	4	4	15	4
Lithuania	10	47	5	4	16	4
Luxembourg						
The Netherlands	1,751	10,615	6	2,246	12,512	6
Norway	190	1,159	6	228	1,276	6
Poland						
Portugal	157	738	5	119	554	5
Russian federation	16	84	5	1,021	6,123	6
Romania	2,195	11,855	5	4	21	5
Serbia	7	25	4	7	25	4
Slovenia	33	158	5	33	158	5
Spain	472	2,578	6	285	2,177	8
Sweden	61	378	6	91	416	5
Switzerland	341	1,780	5	687	4,860	7

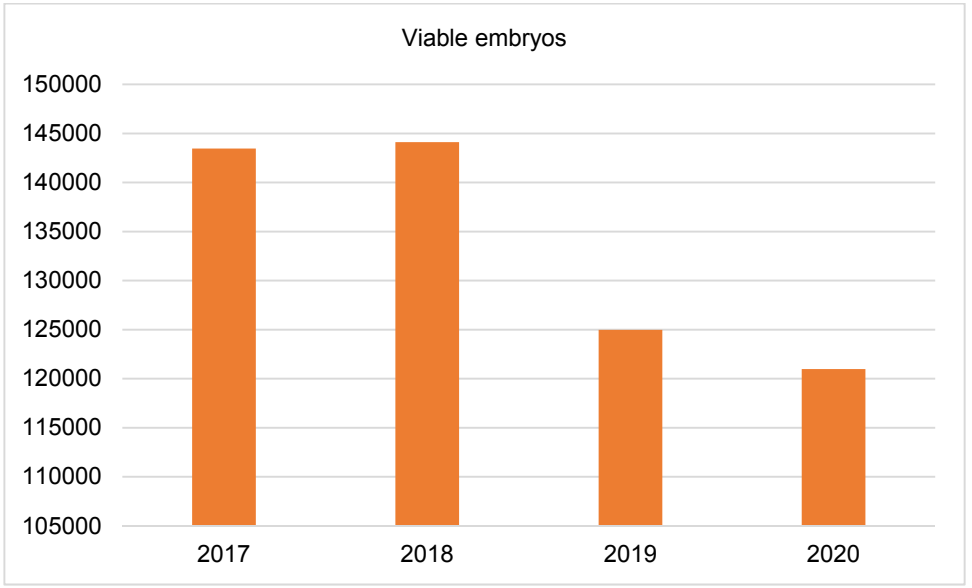

Figure 5 – Number of viable embryos collected in the period between 2017 and 2020 in Europe

In 2018, there was an increase, followed by an increase in 2019 and 2020. This decrease can be explained by the lack of information for Israel, Ireland, Poland, Ukraine and the United Kingdom. The other countries showed increasing numbers of viable embryos collected in the covid period.

In Switzerland, the number of embryo collections increased in 2020, whereas in Italy, it was relatively constant during the studied 4 years, with a slight increase in 2019.

Bovine *in vitro* embryo production (OPU-IVP)

Table 3 shows the number of embryos produced *in vitro* in the period between 2017 and 2020 in Europe.

The UK did not record any information after 2017 and Poland did not report information for 2019 and 2020. Also, the Russian federation did not provide any records in 2020. Thus, the total number of embryos in the year 2020 was lower than that recorded in the other years.

Figure 6 shows a slight decrease in the number of embryos throughout the years. The covid pandemic did not seem to have an impact on embryo production in vitro. In all countries, a small decrease was observed for 2018.

Figure 7 shows the increased production of embryos *in vitro* in 2020 compared to 2017 and 2018 in Switzerland.

Declared bovine embryo transfers and exports – *in vivo*

Table 4 shows the numbers of transferred embryos *in vivo* in Europe from 2017-2020. Ukraine, the UK and Poland did not record any transfers in 2019 and 2020. Israel and Ireland did not record any transfers in 2020, and for Luxembourg, only data from 2017 are available.

Table 3 – Bovine *in vitro* embryo production in the period from 2017–2018

Country	2017	2018	2019	2020
Finland	1,211	462	1,365	1,569
France	1,756	1,211	1,066	2,423
Germany	1,794	2,710	6,845	7,174
Italy	818	186	473	478
The Netherlands	16,695	29,802	11,705	12,657
Poland	34	190	-	-
Russian Federation	26,762	1,559	547	-
Spain	2,746	390	1,185	776
Switzerland	81	145	139	311
United Kingdom	74			
Total	51,971	36,832	31,140	25,388

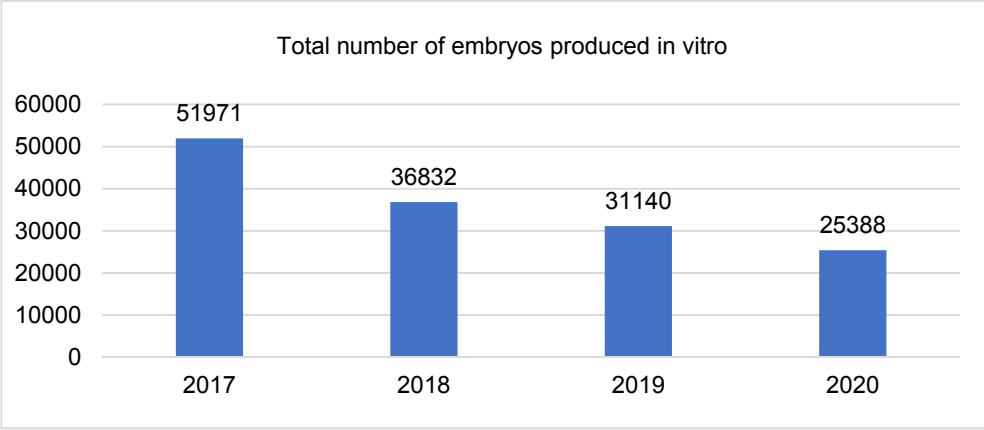

Figure 6 – Histogram representing the number of embryos produced *in vitro* in the period of 2017–2018

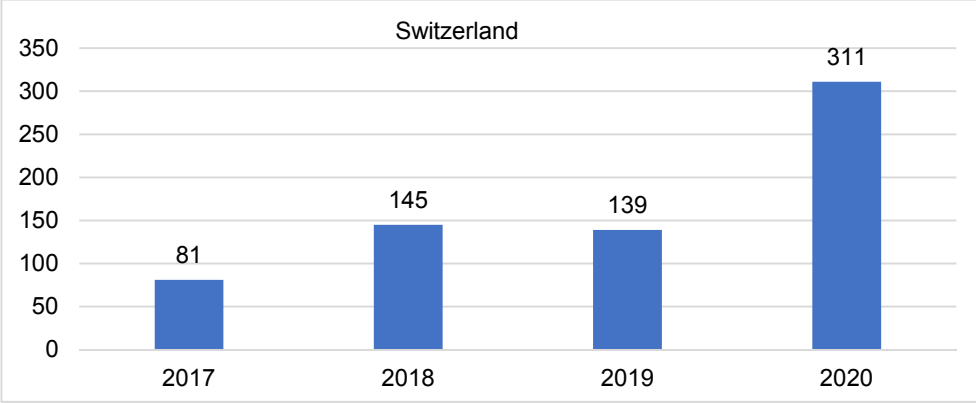

Figure 7 – Numbers of embryos produced *in vitro* in Switzerland in period from 2017–2020

The number of embryo transfers increased from 2017–2018 and then decreased in 2019 and again in 2020 (*Figure 8*). The Russian Federation is one of the countries the reported a huge decrease in the number of transferred embryos *in vivo* in 2020, most likely as a result of the pandemic (*Figure 9*).

The Netherlands is another country for which a huge decrease in the number of transferred embryos was observed, mainly from 2018 to 2020 (*Figure 10*).

Compared to these countries, France reported a slight decrease in the number of embryos transferred.

Other countries, such as Austria, showed an increased ET activity from 2017 to 2020 (*Figure 11*).

Declared bovine embryo transfers and exports – *in vitro*

As seen in *Table 5* and *Table 6* out of the 15 countries did not provide any data in 2020. Romania and Estonia only provided data for 2018.

The number of embryos transferred *in vitro* in Europe decreased each year from 2017 to 2019.

Still, the number of embryos transferred in 2020 was higher compared to that in 2019 (*Figure 12*).

In the Netherlands, the number of transferred embryos *in vitro* increased in 2018, followed by a substantial decrease (from 21,478 to 17) and another increase in 2020.

Table 4 – Declared bovine embryo transfers *in vivo* in Europe in period from 2017–2020

Country	2017	2018	2019	2020
Austria	1,675	2,354	2,623	2,876
Belgium	6,328	4,065	2,865	3,145
Denmark	4,000	3,676	4,411	4,791
Finland	2,461	2,969	1,788	2,459
France	36,022	35,403	33,928	32,676
Germany	21,193	22,598	22,081	23,946
Hungary	276	276		1,057
Ireland	3,853	3,469	1,340	
Israel	200	171	44	
Italy	7,400	7,750	7,450	9,212
Luxembourg	1,205			
The Netherlands	24,171	20,347	2,925	1,169
Norway	343	377	700	1,142
Poland	1,194	1,810		
Portugal	507	564	695	596
Russian Federation	13,710	12,378	13,498	2,897
Spain	2,759	3,223	1,885	1,240
Sweden	619	641	970	1,380
Switzerland	3,919	2,023	2,113	2,011
Ukraine	21	205		
United-Kingdom	262	1,548		
Total	110,925	125,847	99,316	90,597

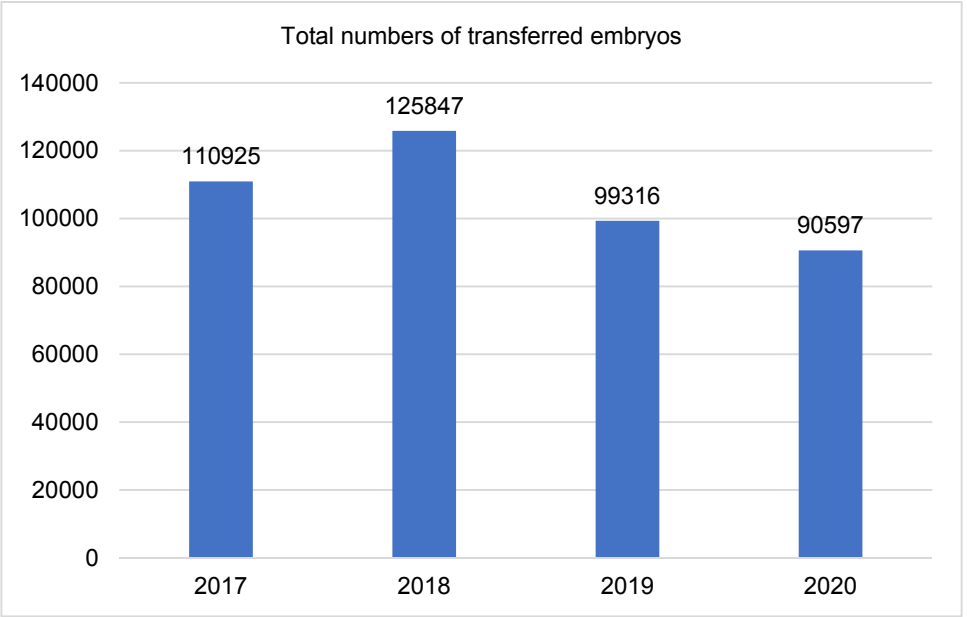

Figure 8 – Histogram representing the total numbers of transferred embryos in Europe from 2017–2020

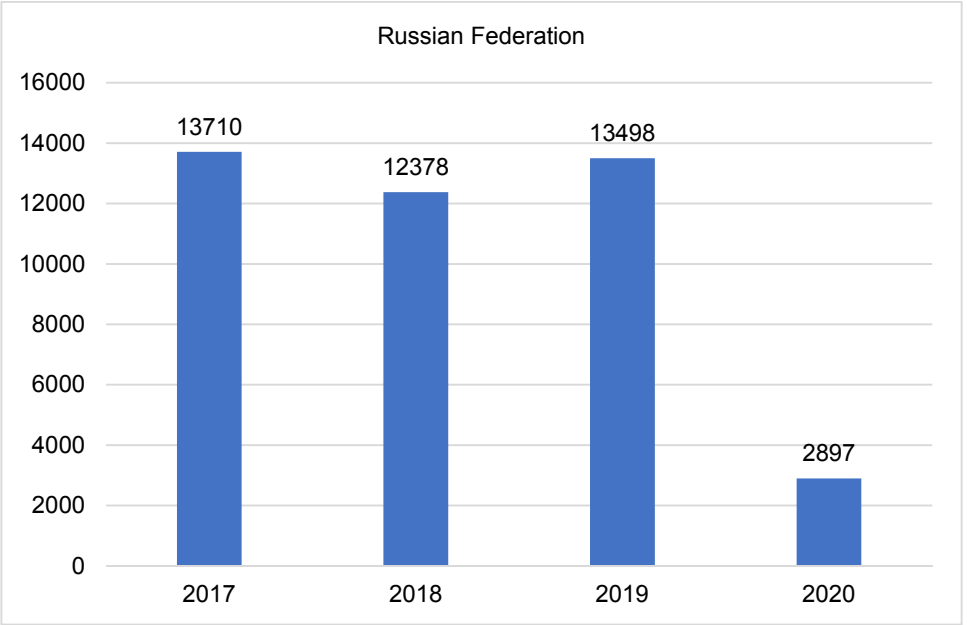

Figure 9 – Histogram representing the number of embryo transfers *in vivo* in the Russian Federation from 2017–2020

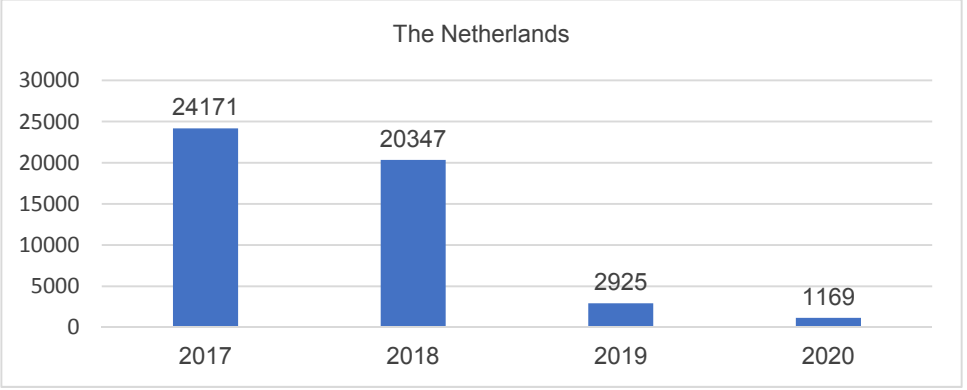

Figure 10 – Histogram representing the number of embryo transfers *in vivo* in the Netherlands from 2017–2020

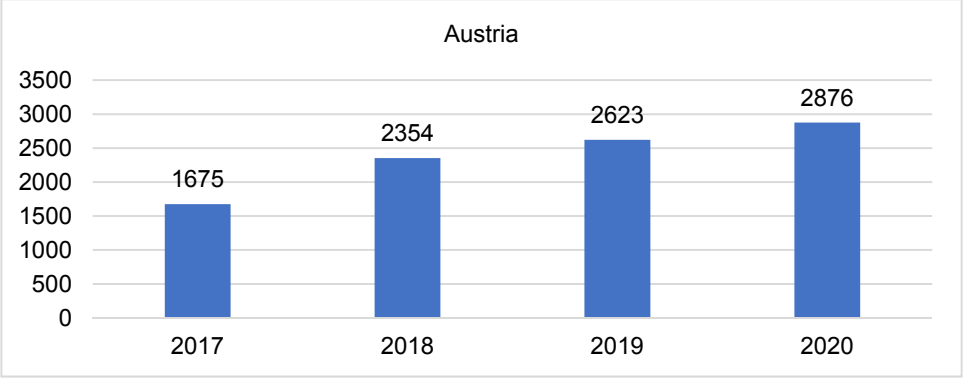

Figure 11 – Numbers of embryos transferred in vivo in Austria from 2017–2020

Table 5 – Declared bovine embryo transfers *in vivo* in Europe from 2017–2020

Country	2017	2018	2019	2020
Belgium		1,315	63	99
Estonia		17		
Finland	847	476	362	1,035
France	1,215	859	745	1,909
Germany	1,682	2,916	7,111	8,330
Hungary	105	105		
Italy	757	141	6,552	368
The Netherlands	15,104	21,478	17	7,268
Poland	23	40		
Romania		16		
Russian Federation	27,960	632	382	
Serbia		49	23	23
Spain	1,918	548	564	517
Switzerland	126	95		
United Kingdom	15	117		
Total	49,752	28,804	15,970	19,588

Table 6 – Declared transfer in sheep – *in vivo*

Country	2017	2018	2019	2020
France	0	0		
Hungary	0	0		
Italy		58		
Portugal			10	0
Romania			8	27
Russian			0	0
Serbia		0	12	12
Sweden	0	0	0	0
United Kingdom	217	3,247		
Total	217	3,305	30	39

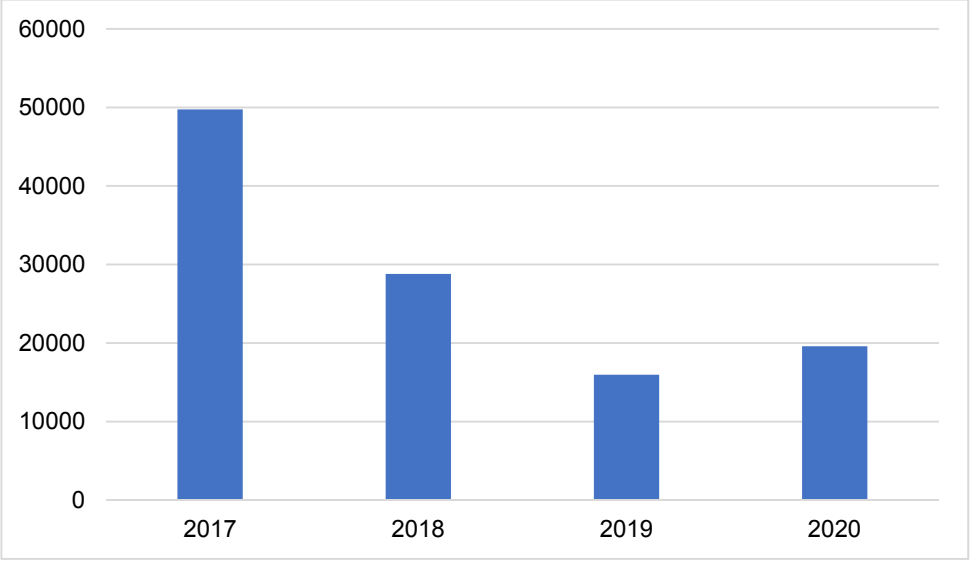

Figure 12 – Total number of embryos transferred *in vitro* in Europe from 2017–2020

Compared to the Netherlands, Germany increased its *in vivo* transfer of embryos from 1,682 in 2017 to 8,330 in 2020 (*Figure 13*).

Declared embryo production, transfer and export in other species – *in vivo*

In sheep, ET is not currently practised in Europe, with the exception of the UK in the years of 2017 and 2018. In 2018, there was a substantial increase in the number of transferred embryos in sheep (*Figure 14*). There is a lack of information about horse embryo transfer in Europe. In 2018, the numbers for the UK were high, whereas those for Spain were constant from 2017 to 2020 (*Table 7*, *Figure 15*). The ET activity in equines was relatively constant compared to that in sheep.

Declared embryo production, transfer and export in other species – *in vitro*

Italy (*in vitro*) and Romania (*in vivo*) were the only countries reporting the collection and transfer of buffalo embryos from 2017–2020 (*Table 8*). In 2019, no activities were reported for any

of the countries. In 2018, the collection of embryos was reported most frequently (with 27 embryos in Italy). Italy is the only country that reported the transfer of horse embryos *in vitro* during this period, although the numbers decreased throughout the years (*Table 9*). The *in vivo* ET in horses increased by almost 40%, whereas the *in vitro* ET increased by 23%.

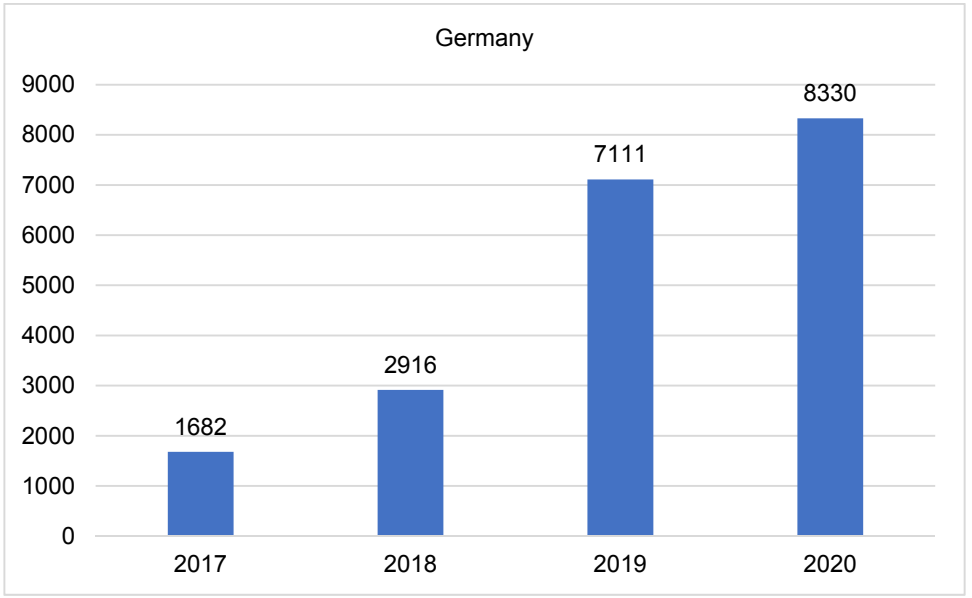

Figure 13 – Total numbers of embryos transferred *in vitro* in Germany from 2017–2020

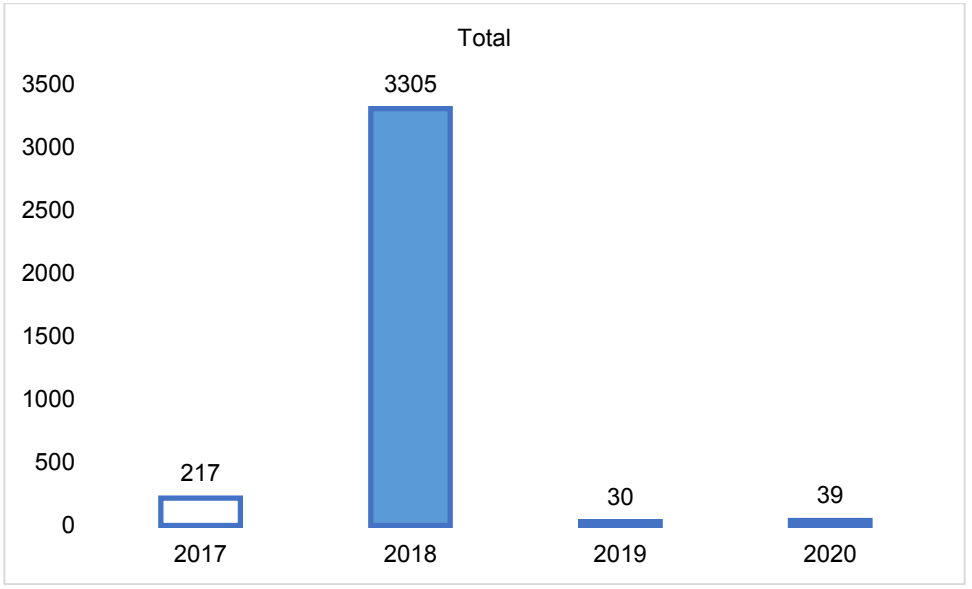

Figure 14 – Numbers of transferred embryos in sheep in Europe in 2017–2020

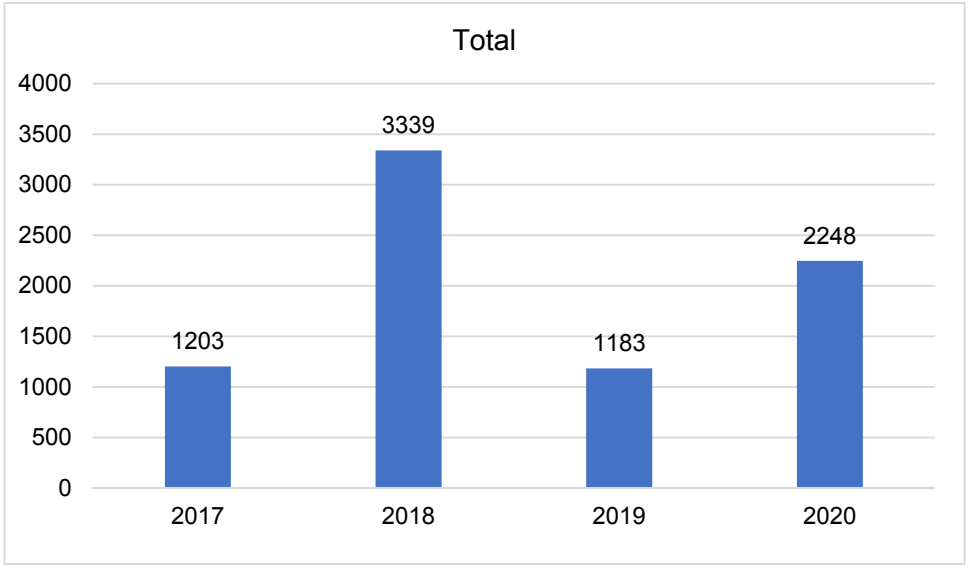

Figure 15 – Numbers of embryos transferred in horses in Europe from 2017–2020

Table 7 – Declared embryo transfer in horses – *in vivo*

Country	2017	2018	2019	2020
France	776	0	939	2,219
Italy	197	58	212	
The Netherlands	164			
Poland	7			
Russian Federation	2		5	3
Spain	12	34	7	2
Sweden	15	0	20	24
Switzerland	30			
United Kingdom	0	3,247		
Total	1,203	3,339	1,183	2,248

CONCLUSIONS

Based on the data collected by the different associations (AETE, IETS), there was a reduction in the number of countries that carried out ET activities, especially on the European continent, during the Covid-19 pandemic. Although 2017 saw the highest number of embryos transferred since 1998, the pandemic appears to have negatively affected this number, with a decline by 31%. However, for equines, there was an increase in ET activity. The number of total viable bovine embryos produced *in vivo* decreased throughout the studied years, probably due to the lack of data from some countries (Russian Federation, Ukraine, the UK) in 2019 and 2020. However, in other countries, the number of viable embryos transferred tended to increase from

2019–2020. The total number of embryos produced *in vitro* decreased from 2017–2020, which is not related to the pandemic. In all countries, a small decrease in embryo production was observed in 2018.

The Russian Federation and the Netherlands reported a large decrease in ET activity after 2018, whereas in Austria, ET activity increased. There is a lack of data about embryo transfer *in vitro* in Europe, and 6 out of the 15 countries did not report any ET activity in 2020. However, in Germany, the *in vitro* ET activity increased throughout the study period. The decrease in the *in vivo* ET activity was most pronounced in equines and sheep, whereas the *in vitro* ET activity increased in equines and buffaloes.

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REFERENCES

AETE. Statistics. https://www.aete.eu/publications/statistics (accessed on 25 May 2023).

Ciornei, S.G. Embryo Transfer. In *Animal Reproduction*. IntechOpen, 2021a. https://doi.org/10.5772/intechopen.99683.

Ciornei, S.G. Sars COV 2 in Animals – The Beginning. *Research Aspects in Agriculture and Veterinary Science*. **2021b**, 4, 30-41. https://doi.org/10.9734/bpi/raavs/v4/4682F.

ECDC (European Centre for Disease Prevention and Control). 'Detection of new SARS-CoV-2 variants related to mink', Stockholm, 12 November 2020.

Emoke, P.; Cenariu, M. *Reproductive biotechnology* (in *Romanian*). Publishing House Colorama, Cluj-Napoca, Romania, 2020.

FAO. World diffusion. https://www.fao.org/worldfoodsituation/foodpricesindex/en/ (accesed on 1 May 2021)

IETS. Data retrieval comitee. https://www.iets.org/Committees/Data-Retrieval-Committee (accessed on 25 May 2023)

Kim, Y.-I.; Kim, S.-G.; Kim, S.-M.; Kim, E.-H.; Park, S.-J.; Yu, K.-M.; Chang, J.-H.; et al. Infection and Rapid Transmission of SARS-CoV-2 in Ferrets. Cell *Host & Microbe*. **2020**, 27, 704-709.e2. https://doi.org/10.1016/j.chom.2020.03.023.

Mircu, C. *Treatise on assisted reproduction* (in *Romanian*). Publishing House Agroprint, Timisoara, Romania, 2020, pp. 139-168.

OIE (World Animal Health Information System) 2020, Information provided by the National Veterinary Services of Belgium, World Organisation for Animal Health. https://www.oie.int/wahis_2/public/wahid.php/Diseaseinformation/WI/index/newlang/en (accesed on 29 April 2020).

Palmer, M.V.; Martins, M.; Falkenberg, S.; Buckley, A.; Caserta, L.C.; Mitchell, P.K.; Cassmann, E.D.; Rollins, A.; Zylich, N.C.; Renshaw, R.W.; Guarino, C. Susceptibility of white-tailed deer (Odocoileus virginianus) to SARS-CoV-2. *Journal*

of virology. **2021**, 95, 10-1128. https://doi.org/10.1128/JVI.00083-21.

Pickering, B.S.; Smith, G.; Pinette, M.M.; Embury-Hyatt, C.; Moffat, E.; Marszal, P.; Lewis, C.E. Susceptibility of Domestic Swine to Experimental Infection with Severe Acute Respiratory Syndrome Coronavirus 2. *Emerging Infectious Diseases*. **2021**, 27, 104-112. https://dx.doi.org/10.3201/eid2701.203399

Toba, G.F.; Ciornei, S.G.; Paraschivescu, M.; Toba, G.L.; Ciornei, L.; Banateanu, F. Identification, monitoring and conservation of the biodiversity of the national heritage of the Romanian buffalo breed, using breeding biotechnologies. Harnessing Tangible and Intangible Assets in the Context of European Integration and Globalization: Challenges Ahead, 2021, I-II, pp.1127-1139.

Viana, J.H.M. Statistics of embryo production and transfer in domestic farm animals: Is it a turning point? In 2017 more in vitro-produced than in vivo-derived embryos were transferred worldwide. *Embryo Transfer Newsletter*. **2018**, 36, 8-25.

Viana, J.H.M. Statistics of embryo production and transfer in domestic farm animals. Embryo production on a new level: over one million embryos produced *in vitro*. *Embryo Transfer Newsletter*. **2019**, 37, 7-25.

Viana, J.H.M. Statistics of embryo production and transfer in domestic farm animals. Divergent trends for IVD and IVP embryos. *Embryo Transfer Newsletter*. **2020**, 38, 7-25.

WHO. Emergiences disease. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline# (accesed 1 May 2021).

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