2020 Statistics of embryo production and transfer in domestic farm animals

World embryo industry grows despite the Pandemic

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1. Executive summary

The International Embryo Technology Society (IETS) Data Retrieval Committee presents the 30th annual report of data collected globally in 2021 on embryo transfer (ET) activities during 2020. The main feature of this year was that, in spite of the COVID-19 Pandemic and its extensive negative effects upon global economy, the world embryo production increased in most regions and all species.

The number of countries reporting ET data in 2020 was the same as 2019 (39 of 202, 19.3%; Table 1), with barely any changes within regions (only two more countries reporting data from Europe, whereas two less from Asia) and minor changes among species (one more country reporting data on cattle and sheep, two more on goats, and one less on horses). Nevertheless, we received data about embryo export to 25 countries that did not submit any data, mainly located in Asia (12 countries). This is evidence of a broader adoption of embryo technologies worldwide (circa 31.7% of the countries).

Table 1. Number and proportion of countries submitting ET data, by region and species

Region	Cattle		Other (IVD + IVP) [1]				% countries within a region
	IVD	IVP	Horses	Sheep	Goats	Other[2]	
Africa	1	1	0	0	0	0	1.9% (1/54)
Asia	0	0	0	0	0	0	0.0% (0/48)
Europe	23	12	6	7	2	1	51.1% (24/47)
North America	3	3	3	3	3	2	100.0% (03/03)
Oceania	1	1	0	1	1	1	14.3% (2/14)
South America[3]	3	9	1	2	1	1	25.0% (9/36)
Total	**31**	**26**	**10**	**13**	**7**	**5**	**19.3% (39/202)**

[1] IVD: *in vivo* derived; IVP: *in vitro* produced
[2] Cervids, camelids, buffalo
[3] South and Central America

The embryo industry's numbers in 2020 on the four most representative farm animal species are summarized in Table 2 (total of embryos produced or collected) and Table 3 (numbers of transferred embryos). For the first time, more than 1,5 million bovine embryos were recorded, which represents an increase of 7.0% compared with 2019 (1,518,150 *vs*. 1,419,336; respectively). As occurred in 2019, divergent trends were observed for *in vivo* derived (IVD) and *in vitro* produced (IVP) embryos. There was a decrease in both numbers of collected and transferred IVD embryos in 2020 (-6.7% and -7.9%, respectively, compared with 2019). This decline follows a tendency observed since 2015 (i.e., far before the Pandemic) and has been fully compensated by an increase in the number of IVP embryos produced and transferred in 2020 (+12.1% and +10.2%, compared with 2019). An opposite trend was only observed in Europe, which reported more IVD (+1.3%) and less IVP (-23.4%) embryos in 2020 than 2019. Worldwide, IVP embryos accounted for 76.2% of all transferrable cattle embryos in 2020.

A heated embryo market was also observed in other species. The numbers of IVD embryos increased in horses (+13.6%), sheep (+33.3%) and goats (+51.0%); and IVP embryos

also increased in horses (+37.1%) and goats (+204.1%) compared with 2019. Interpretation of trends for IVP embryos shall take into account the low proportion of countries reporting such data, particularly in small ruminants, which may result in a high year-by-year fluctuation (e.g., +122.1% from 2018 to 2019 *vs*. -87.6% from 2019 to 2020 for sheep IVP embryos). Nevertheless, in all these species (horses, sheep, and goats) the total embryos recorded in 2020 was the highest for the past five years.

Table 2. Total production (transferrable embryos) of IVD and IVP embryos in 2020 in cattle, sheep, goats, and horses, by region

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	2763	4977	0	0	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Europe	126,491	47,470	2,248	5,359	966	0	346	0
North America	196,704	578,995	851	1,126	9,204	141	10,757	2,275
Oceania	4,211	14,345	0	0	12,427	0	1,890	0
South America	31,559	500,397	22,120	2,156	7,222	0	184	0
Total 2020	**361,728**	**1,156,422**	**25,219**	**8,641**	**29,819**	**141**	**13,177**	**2,275**
Total 2019	387,769	1,031,567	22,198	6,303	22,374	1,137	8,725	748
% Change	-6.7	+12.1	+13.6	+37.1	+33.3	-87.6	+51.0	+204.1

The number of embryos actually transferred followed the same trends observed for embryos collected or produced in 2020, i.e., a decrease in IVD and an increase in IVP (-7.9% and +10.2%, respectively). We detected a slight decrease in the proportion of IVP embryos actually transferred in 2020 (75.9%, *vs*. 77.3% in 2019), driven mainly by North America numbers, where this proportion was the lowest (58.7%). As a consequence, the number of embryo transfers remains still greater in South America than North America (474,145, *vs*. 339,716; respectively). The proportion of frozen-thawed IVD embryos transferred in 2020 was quite similar to 2019 (40.5% *vs*. 39.2%, respectively), whereas transfer of frozen-thawed IVP embryos decreased (39.5% *vs*. 43.9% in 2019). The latter, however, was caused mainly by the increase in transfers of fresh IVP embryos rather than a substantial decrease in the transfer of frozen IVP embryos (+18.8% and -0.8%, respectively, compared with 2019).

Table 3. Transfers of IVD and IVP embryos in 2020 in cattle, sheep, goats, and horses, by region

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	2674	4159	0	0	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Europe	92,811	35,352	2,248	575	3,969	0	71	0
North America	168,726	339,716	2,039	1,126	9,737	93	10,391	1,381
Oceania	3,767	14,571	0	0	12,421	0	1,890	0
South America	26,692	474,145	21,954	2,156	6,573	0	184	0
Total 2020	**294670**	**878181**	**26241**	**3857**	**32700**	**93**	**12536**	**1381**
Total 2019	319,961	797,190	23,546	3,564	22,510	223	7,240	947
% Change	-7.9	+10.2	+11.4	+8.2	+45.3	-58.3	+73.1	+45.8

In summary, 2020 was a good year for the world embryo industry, in spite of the negative economic conjuncture caused by the COVID19 Pandemic. We observed an increase in the total number of embryos transferred in all species analyzed, whereas the main trends of the activity remained unchanged.

2. Introduction

The Data Retrieval Committee (DRC) is the committee of the International Embryo Technology Society (IETS) in charge of gathering, organizing, and publishing the statistics of the embryo industry in domestic farm animals. This year, we present our 30th annual report showing data on global activities related to *in vivo* and *in vitro* embryo collection and transfer in 2020. The results shown in the present report represents the main trends of the embryo industry worldwide in ruminants and horses.

3. Methodology

Data collection followed the standard methodology used in previous years, as defined by the DRC and reported annually in the December issue of the Embryo Technology Newsletter. In summary, embryo technology activity in each country was either reported for by a local data collector or reported individually by practitioners or representatives of commercial companies (e.g., *in vitro* embryo production [IVEP] laboratories). In several countries, the data collector is a member of the national embryo transfer/technology association: Argentina (Sociedad Argentina de Tecnologías Embrionarias, SATE), Brazil (Sociedade Brasileira de Tecnologia de Embriões, SBTE), Canada (Canadian Embryo Transfer Association, CETA), Mexico (Mexican Embryo Transfer Society, META), Peru (Asociación Peruana de Reproducción Animal, ASPRA), the United States (American Embryo Transfer Association, AETA). For the Member States of the European Union and other European countries, data has been submitted by a regional collector on behalf of the Association of Embryo Technology in Europe (AETE). Data has also been reported by ET teams or companies working abroad. In a few countries, this was the sole source of information on embryo activity. In the case of similar data reported by a local representative, however, data coming from such teams or companies were discarded, to avoid double-reporting. The list of regional data collectors and local collaborators is shown in Appendix 1.

Data was directly uploaded into the IETS website by the national collector or sent to the Chair of the DRC. The software managing the database generated MS Excel .csv files with data organized by criteria defined in the data submission form. A summary of the results is shown in Tables 4 to 14, by region, technology (*in vivo*-derived [IVD] or *in vitro*-produced [IVP]), and species. South American numbers include those collected from South and Central America countries. Data has also been used to build historical series, shown in Figures 2 to 4. Detailed country information (Appendix 2 to 6), as well as Figures S1 to S4, are available as supplemental files at the IETS website (www.iets.org/Committees/Data-Retrieval-Committee).

4. Results

Data retrieval

There were barely any changes in the countries reporting ET data from the most representative species in 2020. In cattle, two more countries reported data from Europe (Belarus and Estonia), whereas none reported data from Asia (Israel), in both cases with little impact on totals. This reflects a consolidated network of local collectors and multinational IVP laboratories that kindly collaborate with the DRC, but also highlights the difficulty in expanding data collection to a greater number of countries, especially those lacking local ET societies/associations or with scattered, low-scale ET activity. Nevertheless, low variations in countries reporting data implies that the changes in numbers observed in 2020 actually reflects the main trends of the embryo industry worldwide.

The scenario for species other than cattle was slightly different. Although changes in the number of countries reporting data was relatively low, the fact that one more country reported

sheep data, two more goat data, and one less reported horse data might have impacted total numbers at a greater degree than that observed in cattle. Australia, for example, accounted for 16.7% of all goat embryos recorded in 2020, but did not report any data on this species in 2019. However, despite the potential impact of fluctuations in the number of countries reporting data upon total numbers, the trends for these species were unaffected.

This year, detailed data of embryo export reported by the CETA and specially by the AETA included international trade with a number of countries with no records of ET. This piece of information allowed us to fulfill gaps in the records from South/Central America and Europe, as well as to create a more comprehensive picture of ET activity in Asia. In this region, 12 countries imported bovine embryos from the USA, but none reported ET data. Some of these countries, such as Japan, have well-established ET industries, and the lack of data reported is circumstantial. However, the AETA report also included countries with no previous information of ET activity, such as Nepal or Azerbaijan. Altogether, the association of data reported on within-a-country activity and international embryo trade is evidence of a broader adoption of embryo technologies in farm animals worldwide. In this regard, countries with direct or indirect ET data account for 56.5% of the world cattle population [1].

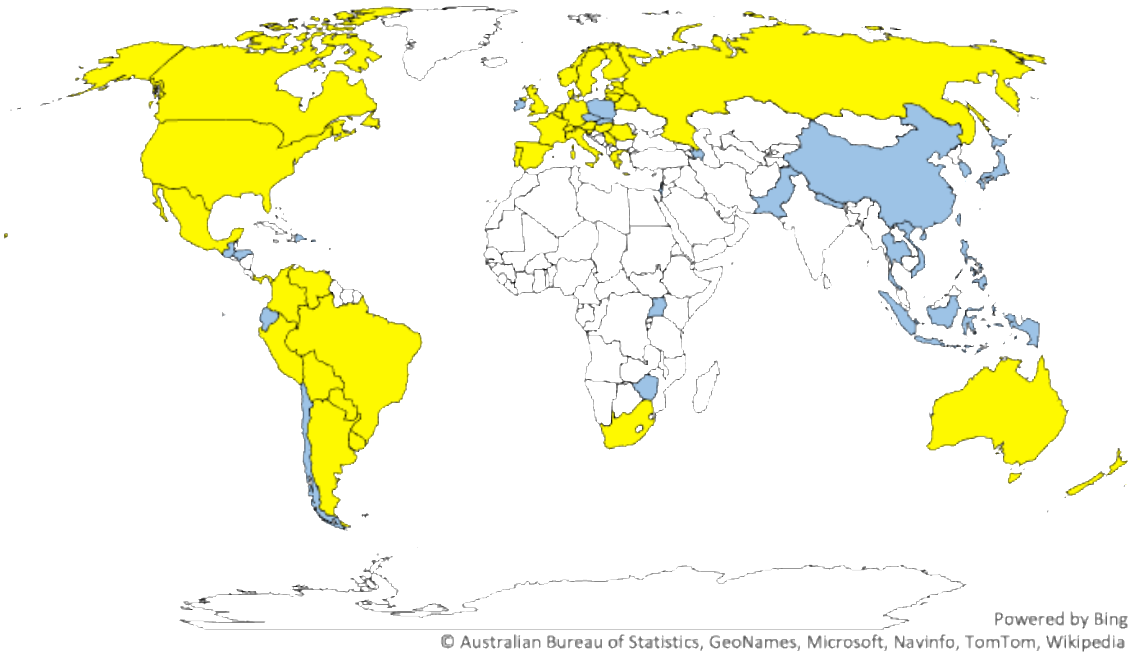

Figure 1. World political map showing the countries that submitted ET data (yellow) or with records about the import of embryos (blue) in 2020. Image generated using Microsoft Excel.

4.1 Embryo industry in numbers

4.1.1 Cattle, IVD

The number of flushes, ova, and transferrable embryos collected in 2020 by region is shown in Table 4 and the number of transfers is shown in Table 5. A total of 361,728 transferrable IVD embryos were collected, representing a reduction relative to the 2019 data (-6.7%) and following the trend observed for this type of embryo since 2015. Among regions, the only exception for this trend has been Europe, where the number of collected IVD embryos had a small increase (+1.3%). Europe was, in fact, the sole region with more countries reporting IVD than IVP embryos (23 *vs.* 12, respectively). Nevertheless, in all regions the number of transfers of IVD embryos decreased, compared with 2019 (overall -7.9%). As a result, in cattle IVD embryos now represents only 23.8% of the total of embryos recorded and 25.1% of the embryos transferred worldwide.

Table 4. Collection of bovine *in vivo* derived [IVD] embryos by region in 2020

Region/ Country	Flushes			Collected					
				Ova			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	10	349	359	165	4045	4,210	93	2,670	2,763
Asia	0	0	0	0	0	0	0	0	0
Europe	17,390	3,040	20,430	158,328	31,976	190,304	106,456	20,035	126,491
N America	12,744	18,547	31,291	116,130	222,391	338,521	69,763	126,941	196,704
Oceania	323	560	883	2,213	4,614	6,827	1,378	2,833	4,211
S America	1,059	4,369	5,428	7,088	38,660	45,748	5,544	26,015	31,559
Total	31,526	26,865	58,391	283,924	301,686	585,610	183,234	178,494	361,728

Europe and North America accounted for the majority of IVD embryos collected and transferred in 2020 (89.3% and 88.8%, respectively). The overall superovulation efficiency remained stable (Figure S1), with an estimated average of 10.0 ova and 6.2 transferable embryos per flush worldwide. Europe was the only region where IVD embryos were collected predominantly in dairy cows and heifers (84.2%), feature observed in 20 out of the 23 countries reporting data within this region (87.0%). Interestingly, superovulation efficiency was similar, for example, to the one observed in North America (6.2 *vs*. 6.3 viable embryos per flush, respectively), where 64.5% of the flushes were done in beef cattle. In dairy breeds within North America, however, less embryos were collected per flush compared with Europe (5.5 *vs*. 6.1, respectively), perhaps explained by the higher proportion of sexed semen use in dairy females in the former compared with the latter (46.1% *vs*. 20.0%).

More IVD frozen-thawed than fresh embryos were transferred (59.5% *vs*. 40.5%, respectively), a proportion slightly different to the observed in 2019 (60.8% *vs.* 39.2%). The use of cryopreserved embryos was predominant in beef (68.6%), but not in dairy breeds (48.8%). Therefore, the proportion of frozen-thawed embryos transferred was greater in North and in South America compared with Europe (63.2% and 61.2% *vs*. 52.2%, respectively).

Table 5. Transfer of bovine *in vivo* derived [IVD] embryos by region in 2020

Region/ Country	Fresh			Frozen domestic			Frozen imported			Total ET
	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	
Africa	15	1,209	0	14	1,181	0	0	255	0	**2,674**
Asia	0	0	0	0	0	0	0	0	0	**0**
Europe	39,755	3,927	680	35,154	8,702	1,600	2,291	523	179	**92,811**
N America	26,736	35,280	0	24,869	80,681	0	148	1,012	0	**168,726**
Oceania	519	855	0	829	1,169	0	179	216	0	**3,767**
S America	2,602	7,765	0	2,694	13,491	0	68	72	0	**26,692**
Total	69,627	49,036	680	63,560	105,224	1,600	2,686	2,078	179	**294,670**

4.1.2 Cattle, IVP

The production of embryos *in vitro* in 2020 is shown in Table 6 (OPU-collected oocytes) and Table 7 (abattoir-derived oocytes). The total number of IVP embryos increased in 2020 (1,156,422 *vs.* 1,031,567 in 2019; +12.1%), contributing decisively to the record of more than 1,5 million bovine embryos collected or produced this year. Once again, the scenario in Europe was distinct from the other regions, with a significant decrease (-23.4%) in the number of IVP embryos produced in 2020 than in 2019. The contrast is more evident when compared with the trends of some other particular regions: +36.5% in Africa, +10.3% in North America,

+36.9% in Oceania, and +18.5% in South America. The totals in Europe, however, were strongly affected by the retraction in the ET activity in Russia (-53.1%, compared with 2019). Conversely, the Netherlands and Germany, the second and third countries in IVP embryo numbers in Europe, recorded increases in the 2020's numbers (+5.5% and +4.8%, respectively).

In the USA, the country with the greatest ET numbers worldwide (Figure S2), IVP totals increased 11.0% in 2020 (526,791 *vs*. 474,437 in 2019), i.e., a greater than two-fold increase in the growth rate observed from 2018 to 2019 (+5.0 %). Similarly, in Brazil, the only country other than the USA with six-digit numbers, the total IVP embryos recorded increased 22.1% in 2020 (366,253 *vs.* 299,870 in 2019), returning to the level of activity observed in 2018. These two countries accounted for 77.2% of all IVP embryos recorded in 2020. In both USA and Brazil, most IVP embryos were from dairy breeds (57.5% and 56.9%; respectively, Figure S3).

Table 6. Production of embryos *in vitro* with OPU-collected oocytes by region in 2020

Region/	Donors			Oocytes			Transferrable embryos		
Country	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	0	866	866	0	12,898	12,898	0	4,301	4,301
Asia	0	0	0	0	0	0	0	0	0
Europe	9,552	4,054	13,606	107,496	67,047	174,543	23,994	18,107	42,101
N America	83,923	39,110	123,033	1,414,822	973,650	2,388,472	323,781	254,424	578,205
Oceania	35	2,685	2,720	264	56,780	57,044	55	14,286	14,341
S America	44,849	37,083	81,932	657,629	800,917	1,458,546	238,132	245,455	483,587
Total	**138,359**	**85,261**	**223,620**	**2,180,211**	**1,940,543**	**4,120,754**	**585,962**	**546,811**	**1,132,773**

The use of FSH stimulation before ovum pick-up (OPU) was reported mainly in North America, followed by Europe, and corresponding to 73.1% and 35.7% of the OPU-IVP embryos, respectively. In other regions, this percentage was less than 1%. The use of FSH stimulation increased particularly in dairy breeds in North America (72.7%, *vs*. 54.7% in 2019). The number of IVP embryos generated using abattoir-derived oocytes in 2020 increased 13.2% (23,649 *vs.* 20,887 in 2019). The proportion abattoir/total, however, was similar to 2019 (2.0%) because IVP totals (OPU + abattoir) also increased. Among regions, the use of abattoir-derived oocytes increased in Europe but decreased in North America (11.3% and 0.1% in 2020 *vs.* 3.4% and 0.8% in 2019, respectively).

Table 7. Production of embryos *in vitro* with abattoir-derived oocytes by region in 2020

Region/	Donors			Oocytes			Transferrable embryos		
Country	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	0	227	227	0	3,895	3,895	0	676	676
Asia	0	0	0	0	0	0	0	0	0
Europe	380	20	400	8,831	12,485	21,316	1,822	3,547	5,369
N America	0	0	0	5,808	0	5,808	790	0	790
Oceania	1	0	1	9	0	9	4	0	4
S America	0	0	0	0	42,025	42,025	0	16,810	16,810
Total	**381**	**247**	**628**	**14,648**	**58,405**	**73,053**	**2,616**	**21,033**	**23,649**

The number of transfers of IVP embryos in 2020 is shown in Table 8. The number but not the proportion of IVP embryos actually transferred in 2020 increased compared with 2019 (878,181 [75.9%] *vs.* 797,190 [77.3%], respectively). As observed in the total of embryos produced, the number of IVP embryo transfers decreased in Europe (-24.8% relative to 2019).

Interestingly, the number of transfers followed the same trend as embryo production and increased in South America, but remained nearly stable in North America (+20.7% and +1.2%, respectively, compared with 2019). Thus, in spite of the greater number of IVP embryos produced in North America, most of IVP embryo transfers were in South America (55.2% of the world total).

The proportion of frozen-thawed IVP embryos transferred decreased from 43.9% in 2019 to 39.5% in 2020. This reduction was caused mainly by the increase in transfers of fresh embryos rather than a significant decrease in the transfers of frozen-thawed embryos (+18.8% and -0.8%, respectively, compared with 2019). The proportion of fresh IVP embryos transferred was similar in Europe and North America, but greater in South America (57.6% and 56.9% *vs*. 63.1%, respectively).

Table 8. Transfer of bovine *in vitro* produced (IVP) embryos by region in 2020

Region/ Country	Embryos transferred							
	OPU				Abattoir			
	Fresh	Frozen		Total	Fresh	Frozen		Total
		Domestic	Foreign			Domestic	Foreign	
Africa	1,483	2,676	0	4,159	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Europe	20,320	14,724	211	35,255	36	61	0	97
N America	193,354	146,275	87	339,716	0	0	0	0
Oceania	10,183	4,384	0	14,567	4	0	0	4
S America	295,444	170,876	0	466,320	6,703	1,122	0	7,825
Total	**524,494**	**345,463**	**298**	**870,255**	**6,743**	**1,183**	**0**	**7,926**

Table 9 shows data regarding embryos micromanipulated for sexing or genotyping in 2020. The use of both sexing and genotyping technologies decreased in IVD, but increased in IVP embryos (-29.1% and -83.8% *vs*. +178.9% and +280.3%, respectively). This clear contrast was predictable, considering the current trends of the world embryo industry.

Table 9. Micromanipulation of bovine embryos for sexing and/or genotyping in 2020

Country	Sexed		Genotyped	
	IVD	IVP	IVD	IVP
Canada	179	9,799	0	9,524
France	1,599	0	1,455	0
Germany	545	14	8	0
Netherlands	0	0	0	4,371
Spain	0	23	0	12
United States	176	0	**39**	35
Total	**2,499**	**9,836**	**1,502**	**13,942**

4.1.3 Other species

The numbers of IVD and IVP embryos reported in 2020 in species other than cattle are shown in Tables 10 (sheep), 11 (goats), 12 (horses) and 13 (cervids, camelids, and buffaloes). A minor change occurred in the number of countries reporting sheep data (13 *vs.* 12 in 2019), particularly the lack of data from Greece and inclusion of data from Peru and Mexico. Contrasting trends were observed in the use of embryo technologies in sheep, with an increase in the number of IVD but a reduction in IVP embryos (29,819 *vs.* 22,374 [+33.3%] and 141 *vs.*

1,137 [-87.6%], respectively, compared with 2019). The USA was the sole country reporting sheep IVP embryos in 2020 but, even there, numbers decreased (141 in 2020 *vs.* 914 in 2019). Australia was the leader country in ovine ET activity, with 12,427 sheep embryos collected and 12,421 transferred, 96.0% of them transferred fresh.

Table 10. Sheep: *in vivo* derived [IVD] and *in vitro* produced [IVP] embryo collections and transfers in 2020

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Europe											
Portugal	0	0	0	8	0	0	0	0	0	0	0
Romania	4	27	27	0	0	0	0	0	0	0	0
Russian Fed.	0	0	0	0	2,683	0	0	0	0	0	0
Serbia	0	0	12	0	0	0	0	0	0	0	0
Spain	3	35	15	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	285	0	0	0	0	0	0
UK	187	904	904	35	0	0	0	0	0	0	0
Total	194	966	958	43	2,968	0	0	0	0	0	0
N America											
Canada	0	0	0	0	516	0	0	0	0	0	0
Mexico	55	396	335	110	0	0	0	0	0	0	0
USA	1,323	8,808	8,319	457	0	33	311	141	93	0	0
Total	1,378	9,204	8,654	567	516	33	311	141	93	0	0
Oceania											
Australia	1,677	12,427	11,927	494	0	0	0	0	0	0	0
Total	1,677	12,427	11,927	494	0	0	0	0	0	0	0
S America											
Brazil	888	7,203	5,616	953	0	0	0	0	0	0	0
Peru	5	19	4	0	0	0	0	0	0	0	0
Total	893	7,222	5,620	953	0	0	0	0	0	0	0
Grand Total	**4,142**	**29,819**	**27,159**	**2,057**	**3,484**	**33**	**311**	**141**	**93**	**0**	**0**

An additional two countries reported ET data in goats in 2020 (Mexico and Australia), the latter with a significant contribution to the total of embryos recorded (14.3%). Differently than what was observed in sheep, both the number of IVD and IVP embryos increased (13,177 and 2,275 *vs.* 8,725 and 748 in 2019; +51.0% and +204.1%, respectively). The number of IVD embryos increased in the Americas (+15.0% in Canada, +35.7% in the USA, +148.6% in Brazil), whereas it decreased in Europe (-62.3% in Spain, -47.1% in the UK). The USA reported most of the IVD embryos (10,465; 79.4% of total) and all IVP embryos (2,275; 100.0%).

The equine embryo industry in 2020 was also characterized by an increase in both the number of IVD and IVP embryos recorded (25,219 *vs.* 22,198 [+13.6%] and 8,641 *vs.* 6,303 [+37.1%], respectively, compared with 2019). Brazil leaded the collection of IVD embryos (22,120; 87.7% of world total), followed by France (2,219; 8.8% of total). Italy remains as the country with more IVP horse embryos (5,345; 61.9% of total). Italy, however, exports the majority of these IVP embryos (50.3%) and only 25 fresh and 527 frozen-thawed embryos were transferred in this country.

Table 11. Goats: *in vivo* derived [IVD] and *in vitro* produced [IVP] embryo collections and transfers in 2020

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Europe											
Spain	17	319	32	12	0	0	0	0	0	0	0
UK	4	27	27	0	0	0	0	0	0	0	0
Total	21	346	59	12	0	0	0	0	0	0	0
N America											
Canada	15	46	8	5	0	0	0	0	0	0	0
Mexico	37	246	246	70	0	0	0	0	0	0	0
USA	1,788	10,465	9,163	899	0	383	8,525	2,275	1,381	0	0
Total	1,840	10,757	9,417	974	0	383	8,525	2,275	1,381	0	0
Oceania											
Australia	230	1,890	1,000	890	0	0	0	0	0	0	0
Total	230	1,890	1,000	890	0	0	0	0	0	0	0
S America											
Brazil	16	184	184	0	0	0	0	0	0	0	0
Total	16	184	184	0	0	0	0	0	0	0	0
Grand Total	**2,107**	**13,177**	**10,660**	**1,876**	**0**	**383**	**8,525**	**2,275**	**1,381**	**0**	**0**

Table 12. Horses: *in vivo* derived [IVD] and *in vitro* produced [IVP] embryo collections and transfers in 2020

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Europe											
France	4,437	2,219	2,219	0	0	0	0	0	0	0	23
Italy	0	0	0	0	0	2,825	28,614	5,345	25	527	0
Russian Fed.	4	3	3	0	0	0	0	0	0	0	0
Spain	2	2	2	0	0	0	0	0	0	0	0
Sweden	29	24	24	0	0	0	0	0	0	0	0
Switzerland	0	0	0	0	0	41	254	14	0	0	0
Total	4,472	2,248	2,248	0	0	2,866	28,868	5,359	25	527	23
N America											
Canada	31	14	14	0	0	0	0	0	0	0	0
Mexico	67	49	49	0	0	0	0	0	0	0	0
USA	1,574	788	1,880	96	0	1,099	6,292	1,126	1,126	0	0
Total	1,672	851	1,943	96	0	1,099	6,292	1,126	1,126	0	0
S America											
Brazil	38,762	22,120	21,954	0	0	0	7,186	2,156	1,059	1,097	0
Total	38,762	22,120	21,954	0	0	0	7,186	2,156	1,059	1,097	0
Grand Total	**44,906**	**25,219**	**26,145**	**96**	**0**	**3,965**	**42,346**	**8,641**	**2,210**	**1,624**	**23**

In 2020, 3,385 IVD and 15 IVP cervid embryos were reported by CETA teams in Mexico, New Zealand and the USA, a little (14.1%) decrease compared with 2019. ET activity in buffalo was reported only by Italy, and in camelids (Llamas and Alpacas) only by Peru.

Table 13. Other species: *in vivo* derived [IVD] and *in vitro* produced [IVP] embryo collections and transfers in 2020

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Cervids											
Mexico	90	385	340	45	0	0	0	0	0	0	0
New Zealand	410	2,000	1,700	200	0	0	0	0	0	0	0
USA	844	3,385	2,890	545	200	5	77	15	0	0	0
Total	90	385	340	45	0	0	0	0	0	0	0
Camelids											
Peru (Llamas)	20	30	5	14	0	0	0	0	0	0	0
Peru (Alpacas)	16	24	15	9	0	0	0	0	0	0	0
Total	36	54	20	23	0	0	0	0	0	0	0
Buffalo											
Italy	0	0	0	0	0	5	216	70	0	8	0
Total	0	0	0	0	0	5	216	70	0	8	0

4.1.4 Exports

Table 14. Countries exporting embryos in 2020

Region/ Country	Bovine					Sheep	Horse
	IVD			IVP		IVD	IVP
	Dairy	Beef	Unsorted	OPU	Abattoir		
Europe							
Austria	41	40	0	0	0	0	0
Belgium	9	13	0	0	0	0	0
Finland	0	0	524	320	0	0	0
France	261	240	0	99	0	0	0
Germany	95	8	0	0	0	0	0
Italy	0	0	0	0	0	0	2,689
Spain	0	152	0	0	0	0	0
Switzerland	48	0	0	0	0	0	0
Total	454	453	524	419	0	0	2,689
N America							
Canada	3,929	2,941	0	1,893	0	0	0
United States	17,153	3,309	0	8,800	0	0	0
Total	21,082	6,250	0	10,693	0	0	0
S America							
Argentina	0	1,024	0	0	0	0	0
Brazil	0	0	0	0	0	0	0
Total	0	1,024	0	0	0	0	0
Grand Total	**21,550**	**8,137**	**524**	**11,112**	**0**	**250**	**2,689**

The numbers of embryo export is shown in Table 14. A greater number of bovine embryos were exported in 2020 compared with 2019 (41,323 *vs.* 38,986; respectively [+6.0%]), with increases in both IVD (+6.6%) and IVP embryos (+4.4%). Moreover, 250 goat IVD embryos were exported by Australia and 2,689 horse IVP embryos were exported by Italy. Exported bovine IVD embryos were predominantly from dairy breeds (71.3%) and all exported cattle IVP embryos were produced with oocytes recovered by OPU.

4.2 Historical series and trends

The historical series of cattle embryo production (IVD, IVP, and total) in the past 20 years (2001 to 2020) is shown in Figure 2. The total number of embryos produced worldwide resumed the trend of growth after a transient decline observed last year. The number of IVP embryos has been growing continuously since 2012 and increased 2.6-fold during this period (2012 to 2020). However, a two-digit growth rate, as observed this year (+12.1%), has not been seen since 2017 [2]. Consequently, during the period 2018-2019 totals were mainly affected by the progressive reductions in the number of IVD embryos collected worldwide since 2005.

The number of IVP and IVD embryos recorded per region are shown in Figures 3A and 3B, respectively. Although the progressive adoption of *in vitro* technologies – and consequent decline in embryo flushing *in vivo* - has proven to be a world trend, the timing of this change differed among regions. The success of IVEP in North and South America resulted in a growing proportion of embryos being produced in these regions, and the "four big" (USA, Brazil, Canada, and Argentina) accounted for 79.2% of all cattle embryos recorded worldwide. In contrast, Europe remains as the only region where flushing is the technique of choice and, in keeping the current trends, may overtake North America as the region with the greatest number of IVD embryos in a few years. The number and the percent share of frozen-thawed IVD and IVP embryos transferred from 2001 to 2020 is shown in Figures 4A and 4B. Interestingly, the evident decline in the number of IVD embryos observed after 2013 coincides with the increase in the number of transfers of frozen-thawed, rather than of fresh, IVP embryos.

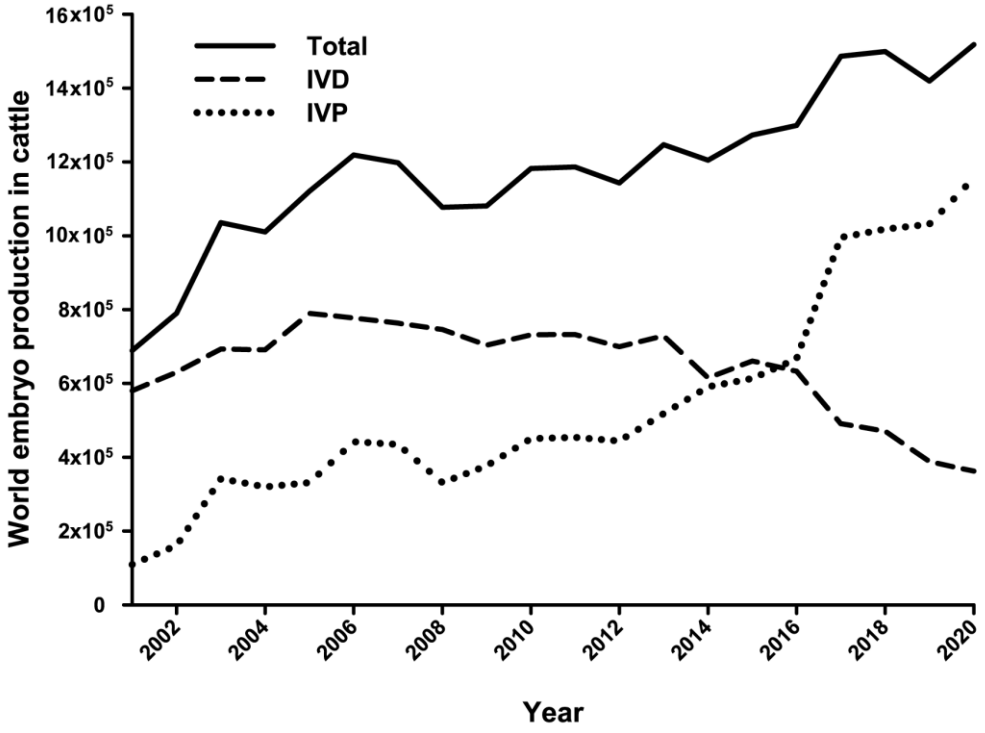

Figure 2. Number of bovine embryos (*in vivo* derived [IVD], *in vitro* produced [IVP], and total) recorded in the period 2001-2020

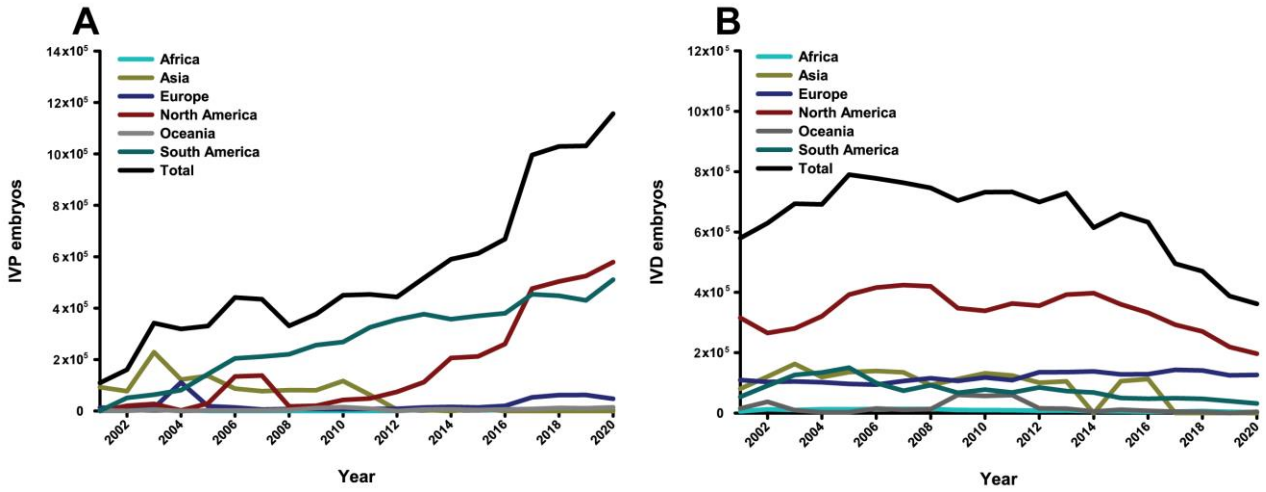

Figure 3 A-B. Number of embryos produced or collected in cattle in the period of 2001-2020, by continent. A) *In vitro* produced [IVP] embryos; B) *In vivo* derived [IVD] embryos

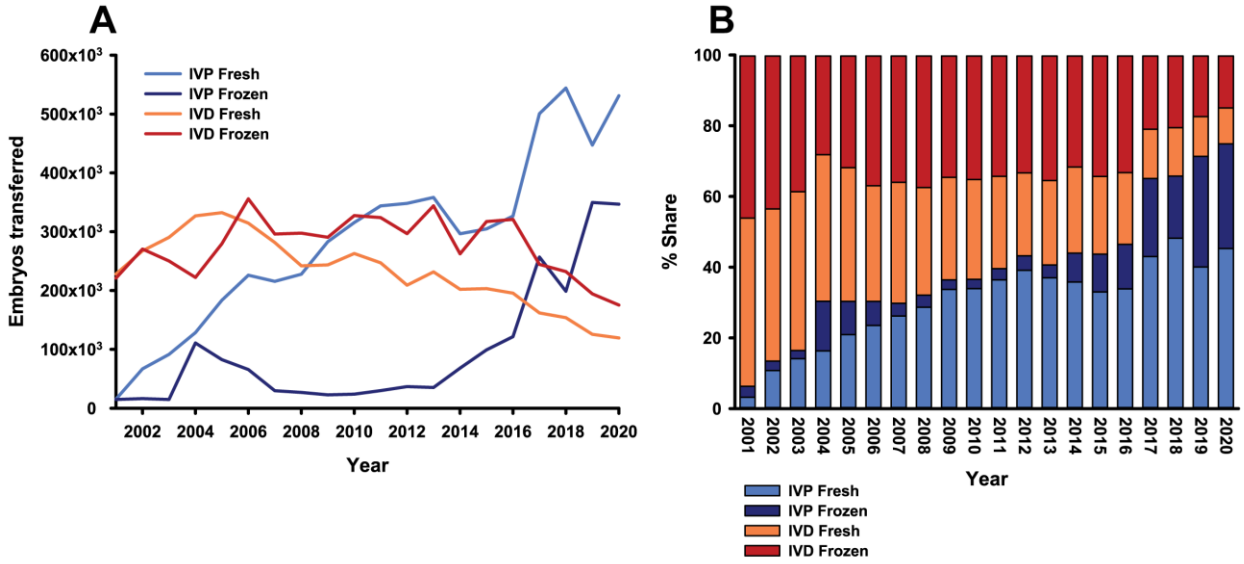

Figure 4 A-B. Embryo transfers in cattle in the period of 2001-2020, according to the origin of the embryo (*in vivo* derived [IVD] or *in vitro* produced [IVP]) and the technique used (fresh or frozen-thawed). A) Number of embryos transferred; B) Percentage share of the total embryo transfers per year.

5. Discussion

The outbreak of Covid19 began in late December, 2019, and was later declared a global Pandemic by the World Health Organization (WHO) on March 11th [3]. Not only a major sanitary and social crisis, the pandemic had huge impacts on global economy. In fact, global DGP decreased by 3.4% in 2020, with most economies facing recession [4], especially in countries ranked as high or middle income (-4.6% and -1.4%, respectively). In this scenario, a depression in world embryo industry could be expected - as observed previously in countries undergoing political or economic crisis. However, the 2020 figures show that the overall embryo activity actually increased, in comparison with 2019. This does not mean that the Pandemic had no effect at all on the embryo industry. It may actually be in the root of this phenomenon. The disorganization of the production chains worldwide elevated prices of many commodities, including animal protein [5]. A number of other concurrent factors such as reductions of meat

exports from Argentina, drought in Australia, the outbreak of African Swine Fever in China, also contributed to boosting the prices of meat and milk on the international markets. The increased demand for meat rapidly created a growing demand for replacement animals and, ultimately, the use of reproductive biotechnologies.

The main features of ET activity in 2020 corroborate this hypothesis. Rather than a local phenomenon, a heated embryo market was observed in most regions and for all species in 2020. Embryo production (IVD+IVP) increased in cattle, sheep, goats, horses, and was the highest for the past five years in these species. In cattle, despite the progressive reduction in numbers of IVD embryos collected and transferred, a two-digit increase (+12.1%) in the number of IVP embryos produced resulted in over 1.5 million embryos reported in 2020, a record. In fact, IVEP has become the technique of choice for embryo production in most of the main players of the international meat market (e.g., Argentina, Australia, Brazil, and the USA, Figure S4), and growing demands for animal protein would naturally reflect on IVP numbers. As IVEP is much more scalable than embryo production by superovulation, in the current scenario it is likely to be the best strategy to respond to a rapid demand for superior genetics.

Another reflex of the heated embryo market worldwide was the increase in cattle embryo exports, particularly to Asia. Data on the international trade of embryos was particularly useful to build a more comprehensive picture of ET activity worldwide. Association of data reported by the local collectors with embryo export data shows that ET technologies are currently adopted by circa 1/3 of the countries, which account for more than half of the world's cattle population. Interestingly, 38 out of 39 (97.4%) countries reporting ET data are classified as developed or developing (ranked as high- or upper-middle-income economies by FAO), whereas 8 out of 25 (32.0%) countries importing embryos but not reporting any data were classified as underdeveloped (ranked as lower-middle- or low-income economies). This observation highlights the difficulty of recovering data from less developed countries, but on the other hand suggests that ET is being recognized as a potential tool to foster livestock production in such poorer areas.

The increase in the number of IVP embryos produced in 2020 has reflected in a similar growth (+18.8%) in the number of transfers of fresh IVP embryos, but not in frozen-thawed IVP embryos (-0.8%). As a consequence, the percentage of IVP cryopreserved embryos demonstrated a small decrease (39.5% *vs*. 43.9% in 2019). Nonetheless, this figure seems to be circumstantial, as transfers of frozen-thawed IVP embryos have grown exponentially over the past decade (+1,058.7% from 2011 to 2020). In fact, the growing adoption of *in vitro* technologies during the previous decade (2001 to 2010) did not cause a significant reduction in the number of IVD embryos collected, but rather a shift towards the use of cryopreservation. In fact, the relatively low pregnancy rates obtained after the transfer of frozen-thawed IVP embryos by then may have preserved a market niche for IVD embryos. However, the technological development and subsequent rapid increase in the number of frozen-thawed IVP embryos transferred after 2013 has been associated not only with a substantial increase in the use of IVEP, but also with a clear trend for reducing the collection of IVD embryos thereafter. In this regard, Europe has diverged from the trends observed in other regions. A number of reasons, from the higher prevalence of low-scale dairy operations to the scattered distribution of ET activity among numerous countries (24 in 2020), may explain the slower adoption of IVEP in Europe and, consequently, the persistency of IVD embryo collection activities. If the current trends were kept, in a few years Europe will overtake North America as the region with more IVD embryos collected.

6. Acknowledgements

The Data Retrieval Committee thank the efforts of all regional data collectors, as well as all practitioners or representatives of ET companies who reported data to the database or

directly to the Chair. The comprehensiveness of the present report is the result of the volunteer collaboration of all these colleagues. The Chair also thank Dr. Luiz G. Siqueira for reviewing this report.

7. References

[1] https://www.fao.org/faostat/en/#data/QCL
[2] Viana JHM. 2017 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, v.36(4), p.8-25, 2018.
[3] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
[4] https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG
[5] https://www.fao.org/worldfoodsituation/foodpricesindex/en/

Appendix 1: National data collectors in 2020

Region/Country	Collector	Region/Country	Collector
Africa		**Europe**	
Rep South Africa	Morne de la Rey	AETE	Héléne Quinton
		Austria	Friedrich Führer
Central America		Belgium	Peter Vercauteren, Isabelle Donnay
Panama	Luis Nasser	Denmark	Henrik Callesen
		Finland	Seija Vahtiala
North America		France	Serge Lacaze
Canada	Reuben Mapletoft (CETA)	Germany	Hubert Cramer
Mexico	Salvador Romo, ABS	Greece	Foteini Samartzi
United States	Daniela Demetrio (AETA)	Ireland	Patrick Lonergan
		Italy	Giovanna Lazzari
South America		Latvia	Vita Antane
Argentina (bovine)	Gabriel Bo	Lithuania	Raisa Nainiene
Brazil (bovine)	Joao Viana	The Netherlands	Helga Flapper, Hilde Aardema
Brazil (equine)	Marco Alvarenga	Norway	Marja Mikkola
Brazil (small rum)	Joanna Souza-Fafjan	Portugal	João Nestor Chagas e Silva
Bolivia	Joao Viana *, ABS	Romania	Stefan Ciornei
Colombia	Joao Viana *, ABS	Russian Federation	Denis Knurow, Viktor Madison, ABS
Paraguay	Joao Viana *, Gabriel Soria	Serbia	Aleksandar Milovanovic
Peru	Edwin Mellisho	Slovenia	Janko Mrkun
Uruguay	Joao Viana *, ABS	Spain	Daniel Martinez Bello, CETA
Venezuela	Joao Viana *, ABS	Sweden	Renée Båge
		Switzerland	Rainer Saner
Oceania		United Kingdom	Roger Sturmey, Brian Graham, CETA
Australia	Cedric M Wise, Genstock WA,		
News Zealand	Reuben Mapletoft (CETA)		

* Data collected/organized by the Chair