

2023 Statistics of embryo production and transfer in domestic farm animals

The number of *in vitro*-produced cattle embryos worldwide is now fivefold greater than that of *in vivo*-derived embryos

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Summary

A total of 2,411,329 embryos were collected or produced in farm animals, representing an overall increase of 13.2% compared with 2022 [1]. The data of the embryo industry in 2023 across the four most representative farm animal species are summarized in Table 1 (total embryos produced or collected) and Table 2 (number of transferred embryos). The number of *in vitro*-produced (IVP) embryos increased in all species: +15.8% in cattle, +62.3% in sheep, +14.9% in horses, and +299.1% in goats. In cattle, the records of *in vivo*-derived (IVD) embryo collections decreased -6.3% compared with 2022, and the number of IVP is now over fivefold greater than IVD embryos. Conversely, the number of IVD embryos collected increased in sheep and horses (+79.1% and + 6.0%, respectively) compared with 2022. Except for sheep IVP embryos, changes in the number of embryos transferred were consistent with those observed in total embryo production or collection. Both the proportions of transferred frozen-thawed IVD and IVP embryos decreased (58.9% vs. 64.8% and 42.1 vs. 44.2%, respectively) compared with 2022.

Table 1. Total production (transferrable embryos) of IVD and IVP embryos in 2023 in cattle, sheep, goats, and horses, by region

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	0	7,368	0	0	0	0	0	0
Asia	35,114	40,328	0	0	0	20,398	1,949	5,485
Europe	132,585	53,824	904	7,106	33,332	200	200	0
North America	156,768	1,093,376	672	3,033	15,417	147	12,803	3,083
Oceania	18,013	38,691	0	0	19,737	0	925	0
South America	28,658	643,004	24,127	6,230	7,598	40	16	0
Total 2023	371,138	1,876,591	25,703	16,369	76,084	20,785	15,893	8,568
Total 2022*	396,247	1,620,347	24,248	14,242	42,470	12,808	17,167	2,147
% Change	-6.3	+15.8	+6.0	+14.9	+79.1	+62.3	-7.4	+299.1

* Data updated after the last report

Table 2. Transfers of IVD and IVP embryos in 2023 in cattle, sheep, goats, and horses, by region

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	0	7,343	0	0	0	0	0	0
Asia	34,345	32,287	0	0	0	5,040	1,949	0
Europe	118,164	27,144	1,077	1,013	2,242	0	0	0
North America	131,882	551,344	1,019	1,079	15,195	332	12,412	3,036
Oceania	14,105	39,149	0	0	19,109	0	877	0
South America	29,002	626,897	23,910	6,230	6,904	0	16	0
Total 2023	327,498	1,284,164	26,006	8,322	43,450	5,372	15,254	3,036
Total 2022*	369,911	1,190,900	23,019	5,977	40,787	7,239	16,486	1,748
% Change	-11.5	+7.8	+13.0	+39.2	+6.5	-25.8	-7.5	+73.7

* Data updated after the last report

1. 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 33rd Annual Report showing data on global activities related to *in vivo* embryo collection, *in vitro* embryo production (IVEP), and embryo transfers during the year 2023. The results shown in the present report represents the main scenario of the embryo industry worldwide in ruminants and horses.

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 by a local data collector or reported individually by practitioners or commercial companies (e.g., 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), China (Animal Reproduction Branch of Chinese Association of Animal Science and Veterinary Medicine, ARB-CAAV) 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 to IETS by embryo transfer (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 data collectors and local collaborators is shown in Appendix 1.

A summary of the results is shown in Tables 3 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 and ranks, shown in Figures 2 to 4 and in Table 15. Detailed country information will be available as supplemental files at the IETS website (www.iets.org/Committees/Data-Retrieval-Committee).

2. Results

Data retrieval

There was a slight decrease in the number of countries reporting data in 2023 (41 vs. 43 in 2022). In Asia, no data was reported from South Korea. On the other hand, we received data from China for both 2022 and 2023, which contributed to a better understanding of the activity in the region. In Europe, there is typically a small fluctuation in the countries submitting ET data. The changes from 2022 to 2023 were that we received data from Estonia, but not from Greece and Serbia. In Oceania, were able to recover data from New Zealand, whereas in South America no data was submitted from Chile or Ecuador. Embryo export records indicate embryo transfer activity in 11 additional countries that did not report any data to this committee. Altogether, these records suggest that embryo technologies are currently used by 27.0% of the countries worldwide.

In cattle, a similar number of countries reported IVD or IVP embryos (30 and 31, respectively). However, in Europe a greater proportion of countries submitted data of IVD embryos, compared with IVP (91.7% vs. 58.3%, respectively), whereas the opposite was observed in South America (33.3% vs. 100.0%). Only minor changes were observed in the

the activity in Australia. Both regions, however, represented only a small share of the global totals (10.5% and 4.3%, respectively), and had little impact on the overall trend.

Table 4. Collection of bovine *in vivo*-derived (IVD) embryos by region in 2023

Region/ Country	Flushes			Collected					
	Dairy	Beef	Total	Ova			Transferrable embryos		
				Dairy	Beef	Total	Dairy	Beef	Total
Africa	0	0	0	0	0	0	0	0	0
Asia	2,869	3,407	6,276	15,114	20,000	35,114	15,114	20,000	35,114
Europe	20,776	3,552	24,328	173,107	36,067	209,174	112,867	19,718	132,585
N America	9,125	15,299	24,424	114,927	183,512	298,439	52,638	104,130	156,768
Oceania	274	3,438	3,712	1,720	4,536	6,256	851	17,162	18,013
S America	3,165	3,134	6,299	15,774	19,094	34,868	14,553	14,105	28,658
Total	36,209	28,830	65,039	320,642	263,209	583,851	196,023	175,115	371,138

Among the top 5 countries in the number of IVD embryos in 2022, an increase in records was observed in 2023 only in France (+12.8%), while decreases were recorded in the USA (-29.8%), Canada (-6.7%), Germany (-11.3%), and Brazil (-20.2%). North America still accounts for the majority of IVD embryos collected worldwide, but its share in the global total decreased from 51.9% in 2022 to 42.2% in 2023. Europe remained the only region in which superovulation was the primary source of cattle embryos. However, the proportion of IVD embryos in Europe decreased from 87.1% of the total in 2022 to 71.1% in 2023. Dairy breeds accounted for 85.1% of the IVD embryos in Europe, 50.8% in South America, 43.0% in Asia, 33.6% in North America, and just 4.7% in Oceania.

No major change was observed in superovulation efficiency, with an estimated worldwide average of 9.0 ova and 5.7 transferable embryos *per* flush in 2023, compared with 8.8 and 5.7, respectively, in 2022. The use of sex-sorted semen declined in 2023, accounting for 31.9% of flushes in dairy breeds and 1.0% of the flushes in beef breeds, compared with 31.9% and 6.5%, respectively, in 2022. Interestingly, in 2023 the proportions of transferred frozen-thawed IVD embryos decreased (58.9% vs. 64.8% in 2022). This reduction occurred in both dairy (49.7% vs. 58.5%) and beef breeds (68.5% vs. 70.5%).

Table 5. Transfers of bovine *in vivo*-derived (IVD) embryos by region in 2023

Region/ Country	Fresh			Frozen domestic			Frozen imported			Total ET
	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	
Africa	0	0	0	0	0	0	0	0	0	0
Asia	9,000	0	0	6,114	18,000	0	754	477	0	34,345
Europe	46,960	6,149	0	50,463	10,333	0	3,071	1,188	0	118,164
N America	16,563	34,474	0	17,159	63,151	0	269	266	0	131,882
Oceania	402	3,378	0	269	9,820	0	82	154	0	14,105
S America	10,977	6,622	0	4,734	6,576	0	41	52	0	29,002
Total	83,902	50,623	0	78,739	107,880	0	4,217	2,137	0	327,498

2.1.2 Cattle, IVP

The *in vitro* production of embryos in 2023 is summarized in Table 6 (OPU-collected oocytes) and Table 7 (abattoir-derived oocytes). The number of IVP embryos reported worldwide increased by 15.8% compared to the previous year, more than double the growth rate observed from 2021 to 2022 (+6.3%). Nearly all regions recorded increases in IVP embryo records: +122.7% in Asia, +23.0% in Europe, +87.5% in Oceania, and +29.8% in North America.

South America, however, reported a decrease of -6.6% compared with 2022. This positive scenario was particularly consistent in North America, where numbers increased in Canada (+68.9%), Mexico (+14.7%), and in the USA (29.8%), resulting in over 250,000 more IVP embryos than in 2022. Notably, in Canada, the number of IVP embryos surpassed IVD embryos for the first time (46,027 vs. 40,756, respectively). The USA approached one million IVP embryos (968,043), more than twice the number recorded in Brazil, the country with the second greatest IVEP figures.

This trend was not that homogeneous in other regions. Among the European countries with the most significant IVEP activity (>5,000 embryos in 2023), IVP embryo numbers increased in France (+23.7%), the Netherlands (+53.3%), and in the UK (+50.5%), but decreased in Germany (-14.4%), and Spain (-11.9%). In South America, IVP embryo records rose in Bolivia (+56.0%), Brazil (+3.1%), Panama (+9.8%), and Uruguay (+26.0%), but declined in Argentina (-4.2%), Colombia (-48.2%), and Paraguay (-25.3%). The drop in numbers from Argentina is likely associated with the economic crises in this country, whereas in Paraguay and Colombia this may reflect underreporting rather than an actual reduction in IVEP.

Table 6. Production of embryos *in vitro* with OPU-collected oocytes by region in 2023

Region/ Country	Donors			Oocytes			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	370	862	1,232	6,740	15,726	22,466	2,210	5,158	7,368
Asia	5,298	8,298	13,596	57,488	84,035	141,523	16,615	23,713	40,328
Europe	13,241	1,419	14,660	148,768	16,656	165,424	37,684	5,543	43,227
N America	126,215	78,058	204,273	2,835,956	2,151,039	4,986,995	523,817	568,164	1,091,981
Oceania	3,605	6,343	9,948	53,722	99,828	153,550	13,885	24,800	38,685
S America	94,823	37,105	131,928	1,261,184	771,149	2,032,333	375,635	265,280	640,915
Total	243,552	132,085	375,637	4,363,858	3,138,433	7,502,291	969,846	892,658	1,862,504

Brazilian official records rely on data from ET communications submitted to the breeders' associations. However, since 2015 we observe a growing market for low-cost embryos, which are typically not registered by these associations. In fact, 1,035,870 ET sheaths were sold in Brazil in 2023, a figure 119.6% higher than the official records of IVD and IVP embryos combined. Therefore, the actual number of embryos produced and transferred in Brazil (and, by extension, the figures for South America) are certainly underestimated.

The number of IVP embryos produced using abattoir-derived oocytes in 2023 decreased (-35.3%; 14,087 vs. 21,767 in 2022), primarily due to a substantial reduction in South America (-78.0%). As a result, these embryos now account for only 0.8% of the total IVP.

Table 7. Production of embryos *in vitro* with abattoir-derived oocytes by region in 2023

Region/ Country	Donors			Oocytes			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	0	0	0	0	0	0	0	0	0
Asia	0	0	0	0	0	0	0	0	0
Europe	911	1,037	1,948	32,646	11,802	44,448	7,805	2,792	10,597
N America	242	223	465	2,588	4,340	6,928	360	1,035	1,395
Oceania	1	0	1	57	0	57	6	0	6
S America	28	0	28	112	6,860	6,972	31	2,058	2,089
Total	1,182	1,260	2,442	35,403	23,002	58,405	8,202	5,885	14,087

There was a slight decrease in the use of FSH stimulation before ovum pick-up (OPU) in 2023 (38.7% vs. 40.7% in 2022). Actually, the use of FSH increased in dairy breeds (55.8% vs. 43.8%), but decreased sharply in beef breeds (7.2% vs. 36.6%) compared with 2022. In Europe and North America, most OPU were carried out after FSH stimulation (93.0% and 61.4%, respectively). In Oceania and South America, these proportions remain very low (<1%), but the use of FSH is likely underreported.

The number of transfers of IVP embryos in 2023 is shown in Table 8. The total transfers of IVP embryos (OPU plus abattoir) increased by +7.8% (1,284,164 vs. 1,190,900), compared with 2022. The proportion of IVP embryos produced and actually transferred, however, decreased (68.4 vs. 73.6%, respectively). This proportion has been particularly low in Europe and North America (it was 50.4% in both regions in 2023), compared with over 80% in all other regions. In the USA, country currently leading in IVEP, only 48.6% (470,834 out of 968,043) of the IVP embryos were actually transferred. Nevertheless, the USA recorded the greatest number of IVP embryo transfers worldwide, accounting for 26.8% of all records.

Table 8. Transfer of bovine *in vitro*-produced (IVP) embryos by region in 2023

Region/ Country	Embryos transferred							
	OPU				Abattoir			
	Fresh	Frozen		Total	Fresh	Frozen		Total
		Domestic	Foreign			Domestic	Foreign	
Africa	1,062	6,281	0	7,343	0	0	0	0
Asia	8,382	23,905	0	32,287	0	0	0	0
Europe	11,795	12,399	572	24,766	765	1,346	267	2,378
N America	332,746	217,131	175	550,052	660	632	0	1,292
Oceania	12,812	26,295	36	39,143	6	0	0	6
S America	374626	251182	156	625964	835	98	0	933
Total	741,423	537,193	939	1,279,555	2,266	2,076	267	4,609

We observed a slight decline in the proportion of frozen-thawed IVP embryos transferred in 2023, relative to 2022 (42.1 vs. 44.2%, respectively). This change, however, resulted from an 11.9% increase in the transfer of fresh embryos rather than a reduction in the use of cryopreservation. Consequently, the relative proportion of frozen-thawed IVP embryos, when considering the total number of embryo transfers (IVD + IVP), remained stable (33.5%, vs. 33.7% in 2022).

In 2023, only Canada, France, Germany, and the Netherlands reported micromanipulation of embryos (Table 9). Therefore, numbers are likely underreported. Yet, as these countries also provided data in 2022, they are useful to infer trends for this technology.

Table 9. Micromanipulation of bovine embryos for sexing and/or genotyping in 2023

Country	Sexed		Genotyped	
	IVD	IVP	IVD	IVP
Canada	0	9,135	0	9,135
France	477	0	701	46
Germany	0	0	242	346
Netherlands	0	0	0	7,046
Total	477	9,135	943	16,573
2022	471	8,916	678	13,224
Difference	+1.3	+2.5	+39.1	+25.3

We observed a slight increase in embryo sexing and a significant rise in genotyping compared with 2022 (+1.3%, +2.5%, +39.1% and +25.3% for IVD sexed, IVP sexed, IVD genotyped and IVP genotyped, respectively). These figures are in line with the general trends current observed for IVD and IVP embryos in cattle. The number of IVP embryos sexed or genotyped from Canada were identical, indicating that the same micromanipulation procedure was applied for both purposes.

2.1.3 Other species

The numbers of IVD and IVP embryos reported in 2023 for species other than cattle are presented in Tables 10 (sheep), 11 (goats), 12 (horses) and 13 (camelids and cervids).

Table 10. Sheep: *in vivo*-derived (IVD) and *in vitro*-produced (IVP) embryo collections and transfers in 2023

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Asia											
China	0	0	0	0	0	3,900	81,144	20,398	4,409	631	0
Total	0	0	0	0	0	3,900	81,144	20,398	4,409	631	0
Europe											
Hungary	2	8	0	0	0	0	0	0	0	0	0
Portugal	13	25	23	9	0	0	0	0	0	0	0
Romania	10	50	50	0	0	0	0	0	0	0	0
Russian Federation	140	1,745	1,065	131	0	0	0	0	0	0	0
Spain	13	55	55	121	129	0	0	0	0	0	0
Sweden	0	0	0	0	230	0	0	0	0	0	0
United Kingdom	4,104	31,449	353	76	0	40	200	200	0	0	0
Total	4,282	33,332	1,546	337	359	40	200	200	0	0	0
N America											
Canada	17	66	57	12	49	0	0	0	0	0	0
Mexico	84	458	375	83	0	0	0	0	0	0	190
United States	2,573	14,893	12,743	1,876	0	122	1,391	147	105	37	0
Total	2,674	15,417	13,175	1,971	49	122	1,391	147	105	37	190
Oceania											
Australia	2,678	19,737	16,331	2,285	493	0	0	0	0	0	0
Total	2,678	19,737	16,331	2,285	493	0	0	0	0	0	0
S America											
Argentina	66	218	152	62	0	0	0	0	0	0	0
Brazil	916	7,281	6,271	320	0	0	0	0	0	0	0
Panama	0	0	0	0	0	18	140	40	0	0	0
Peru	21	99	91	8	0	0	0	0	0	0	0
Total	1,003	7,598	6,514	390	0	18	140	40	0	0	0
Grand Total	10,637	76,084	37,566	4,983	901	4,080	82,875	20,785	4,514	668	190

Among these, sheep had the most active embryo industry, with 96,869 embryos collected or produced in 2023. Both the number of IVD and IVP embryos increased compared with 2022 (+79.1% and +62.3%, respectively).

The changes in IVP sheep embryos were primarily driven by data from China, which reported 12,808 and 20,398 embryos produced in 2022 and 2023, respectively. With these numbers, China leads the use of *in vitro* technologies in sheep worldwide, far surpassing the UK, which reported 200 IVP embryos. Conversely, the UK reported the greatest number of IVD embryos collected (31,449; 41.3% of the total), followed by Australia (19,737) and the USA (14,893). Notably, the UK reported the transfer or export of only 429 IVD embryos, while the USA, Australia, and Brazil accounted for 94.1% of all IVD sheep embryos actually transferred. This explains why the overall number of IVD embryos increased by +79.1% from 2022 to 2023, whereas the number of transfers rose by only +6.5% during the same period. It is also noteworthy that, in 2023, China reported 230 OPU in sheep in which *in vitro* fertilization was carried out using sex-sorted semen.

As observed in recent years, the USA continues to lead the embryo industry in goats, accounting for 79.1% of all IVD embryos collected in 2023. The number of IVD embryos collected in Australia dropped to 925, compared with 2,051 in 2022, falling below China's total (1,949). China also reported the production of 5,485 IVP goat embryos, representing 64.0% of the global total. However, no data were provided regarding the transfer of these embryos. In contrast, the USA transferred most of its IVP embryos (98.5%, 3,036 out of 3,083), driving the +73.7% increase observed in IVP transfers in 2023 compared with 2022.

Table 11. Goats: *in vivo*-derived (IVD) and *in vitro*-produced (IVP) embryo collections and transfers in 2023

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Asia											
China	272	1,949	783	1,166	0	1,159	28,859	5,485	0	0	0
Total	272	1,949	783	1,166	0	1,159	28,859	5,485	0	0	0
Europe											
UK	20	200	0	0	0	0	0	0	0	0	0
Total	20	200	0	0	0	0	0	0	0	0	0
N America											
Mexico	37	234	215	19	0	0	0	0	0	0	0
USA	2,131	12,569	10,427	1,751	0	579	10,791	3,083	2,478	558	0
Total	2,168	12,803	10,642	1,770	0	579	10,791	3,083	2,478	558	0
Oceania											
Australia	147	925	665	205	7	0	0	0	0	0	0
Total	147	925	665	205	7	0	0	0	0	0	0
S America											
Peru	3	16	16	0	0	0	0	0	0	0	0
Total	3	16	16	0	0	0	0	0	0	0	0
Grand Total	2,610	15,893	12,106	3,141	7	1,738	39,650	8,568	2,478	558	0

In horses, although embryo flushing was reported by 12 countries in 2023, most of the IVD embryos recorded were from Brazil (24,127; 93.9% of the total). Changes in Brazil accounted for most of the increase in the number of IVD embryos collected (+6.0%) and actually

Camelids											
Peru (Llamas)	32	59	29	30	0	0	0	0	0	0	0
Peru (Alpacas)	16	34	34	0	0	0	0	0	0	0	0
Total	48	93	63	30	0	0	0	0	0	0	0
Other											
Portugal (swine)	0	0	0	0	0	0	0	20	0	20	
Romania	23	99	99	0	0	0	0	0	0	0	0
Total	23	99	99	0	0	0	0	20	0	20	
Grand Total	94	297	180	30	0	0	0	20	0	20	

2.1.4 Exports

Table 14. Countries exporting embryos in 2023

Region/ Country	Bovine				Sheep IVD	Goats IVD	Horse IVP
	IVD Dairy	Beef	IVP OPU	Abattoir			
Europe							
Austria	298	0	0	0	0	0	0
Denmark	10	0	0	0	0	0	0
France	131	503	0	0	0	0	0
Germany	864	0	0	0	0	0	0
Hungary	0	6	0	0	0	0	0
Italy	0	0	0	0	0	0	3,813
Spain	0	84	0	0	0	0	0
Switzerland	657	22	0	0	0	0	0
United Kingdom	19	229	369	0	0	0	0
Total	1,979	844	369	0	0	0	3,813
N America							
Canada	1,772	1,700	2,086	0	0	0	0
United States	13,232	1,418	9,371	0	0	0	0
Total	15,004	3,118	11,457	0	0	0	0
Oceania							
Australia	28	1,925	0	0	872	219	0
Total	28	1,925	0	0	872	219	0
S America							
Argentina	0	400	0	0	0	0	0
Total	0	400	0	0	0	0	0
Grand Total	17,011	6,287	11,826	0	872	219	3,813

In 2023, 13 countries reported the export of a total of 40,028 embryos from farm species (Table 14). Overall, export trends reflected those observed in embryo collection or production. For instance, we observed a decrease in the exports of IVD embryos in cattle (-45.5%) and goats (-33.4%), and an increase in IVD embryos in sheep (+151.3%) and IVP embryos in cattle (+63.8%) and horses (+4.8%), compared with 2022. Nevertheless, as IVD cattle embryos still accounted for the majority of the exports worldwide, the overall export balance was negative in 2023 compared with 2022 (-26.3%). No country reported the export of embryos generated from abattoir-derived oocytes. However, the Russian Federation reported the transfer of 267

imported IVP embryos produced from abattoir ovaries. Only Australia reported exports of IVD embryos from sheep and goats, and Italy was the sole exporter of IVP embryos from horses in 2023.

2.2 Historical series and trends

The historical series are of special interest because they illustrate medium- to long-term trends in the global embryo industry, helping to avoid misinterpretations caused by year-to-year fluctuations. The series of cattle embryo production (IVD, IVP, and total) over the past 20 years (2004 to 2023) is shown in Figure 2. The number of IVP embryos has been increasing uninterruptedly for the past 12 years, nearly doubling the total number of records during this period (+96.6%). In contrast, the number of IVD embryos has resumed its downward trend, which has been ongoing since 2015, except for a slight increase (+9.5%) observed between 2020 and 2022. However, due to the current disparity in magnitude between IVD and IVP numbers, the reduction in the IVD embryos did not compensate the increase in IVP and thus had little impact on the overall total (IVD + IVP). We can also infer that the current growth in IVP embryo records has been driven by an expansion of the cattle embryo market rather than merely the replacement of superovulation by the use of *in vitro* technologies.

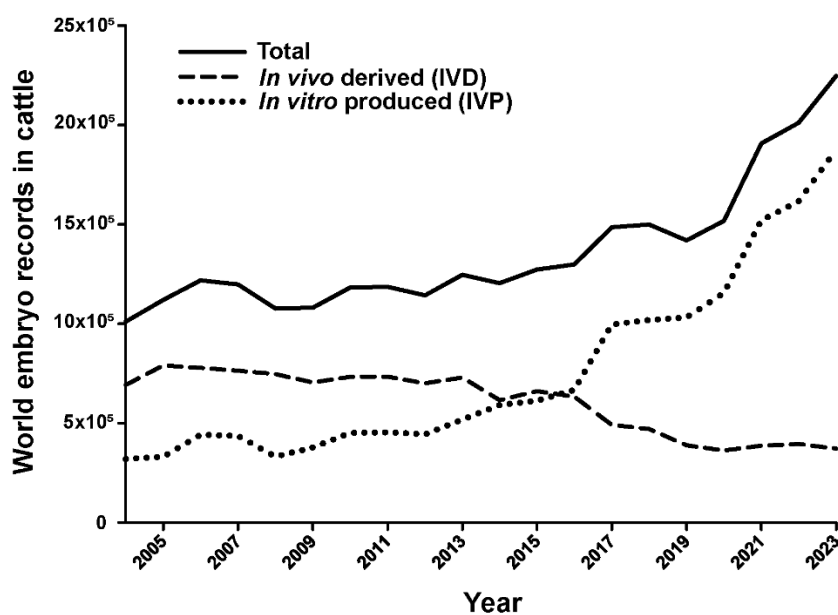


Figure 2. Number of bovine embryos (*in vivo*-derived [IVD], *in vitro*-produced [IVP], and total) recorded in the period 2004-2023.

The numbers of IVP and IVD embryos recorded by region are shown in Figures 3A and 3B, respectively. Over the past 10 years, the use of IVP embryos has grown substantially in North America (+430.4%) and, to a lesser extent, in South America (+80.1%), while in both regions, the use of IVD embryos declined (-60.5% and -58.0%, respectively). In Europe, IVEP has also increased significantly (+243.0%), but the number of IVD embryos recorded has remained relatively stable during this period (-3.9%). The trends in the use of IVP embryos started to diverge between North and South America over the past three years, with a sharp rise in the former, contrasting with relative stabilization in the latter.

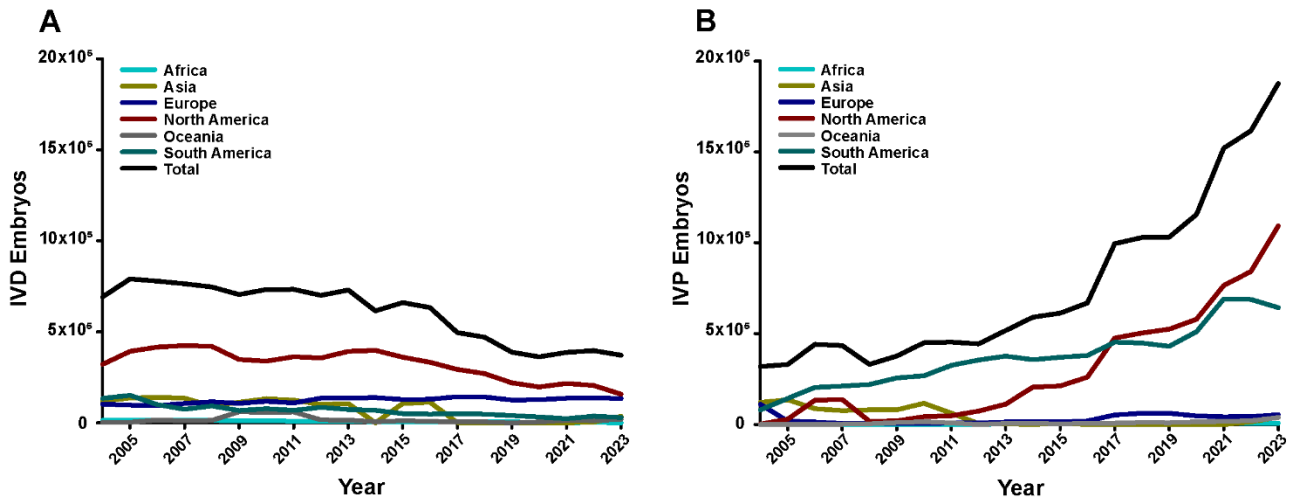


Figure 3 A-B. Number of embryos produced or collected in cattle in the period of 2004-2023, by continent. A) *In vivo*-derived (IVD) embryos; B) *In vitro*-produced (IVP) embryos.

The number and the percent share of frozen-thawed IVD and IVP embryos transferred from 2004 to 2023 are shown in Figures 4A and 4B. The increase observed in the total number of IVP embryos transferred in 2023 (+7.8%) was driven primarily by fresh transfers, which rose by 11.9% compared with 2022, whereas the transfer of frozen-thawed IVP embryos increased by only 2.7% in this period. Conversely, the decrease in the total number of IVD embryos transferred in 2023 (-11.5%) was due to the reduction in transfers of frozen-thawed embryos (-19.2%), but not of fresh embryos (+3.3%).

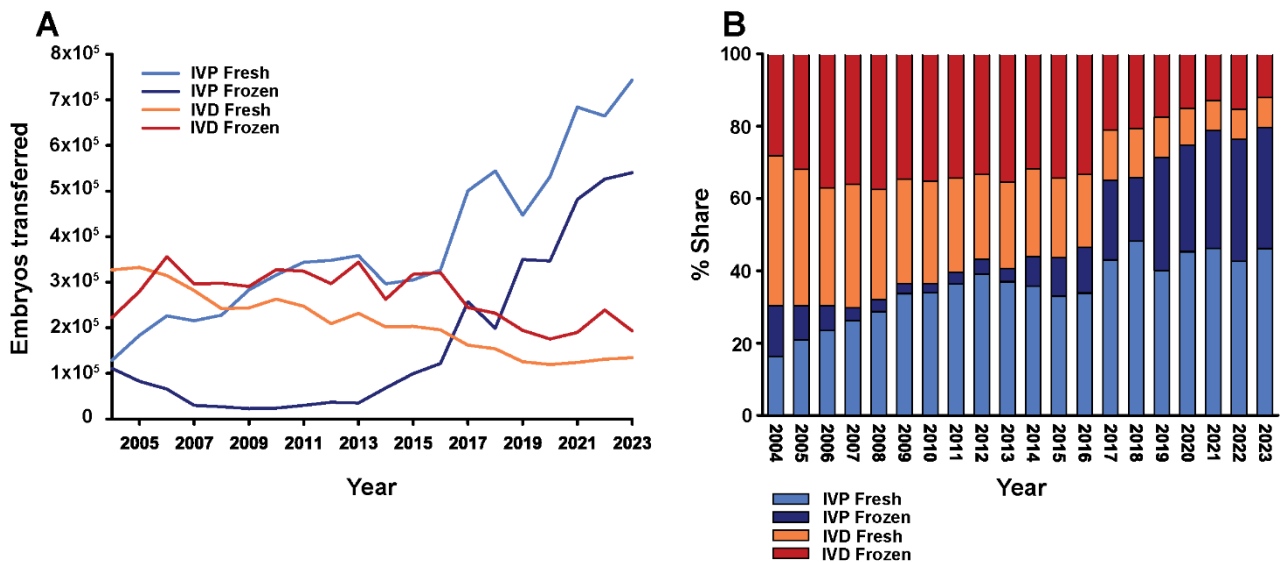


Figure 4 A-B. Embryo transfers in cattle in the period of 2004-2023, according to the technique used (*in vivo*-derived [IVD] or *in vitro*-produced [IVP]) and type of embryo (fresh or frozen-thawed). A) Number of embryos transferred; B) Percent share of the total embryo transfers per year.

2.3 Embryo industry rank

Since 2021, we have been using an index to estimate the intensity of embryo technologies use in cattle, taking into account the size of cattle inventories in each country. According to this methodology, the top five countries in the intensity rank for 2023 remained

unchanged from 2022. However, the index value for all these countries increased compared with previous years, reflecting the ongoing global expansion in the use of embryo technologies, particularly IVEP. As expected, there were some fluctuations among the remaining countries in the top 20 list (Table 15). In some cases, such as the absence of South Korea and Ecuador, or the lower position of Colombia, these changes are more likely attributed to underreporting rather than a decrease in ET activity.

Table 15. Top 20 countries according to the ET intensity index in 2023. This index considers the ratio between the number of embryos recorded and the size of the cattle inventory in each country.

Country	Embryos ¹	Embryo rank	Cattle herd ²	Herd rank ³	Index ⁴	Intensity Rank
United States	1,077,707	1	92,076,600	3	117.0	1
Netherlands	36,452	10	3,751,000	63	97.2	2
Canada	86,783	4	11,515,000	30	75.4	3
Panama	7,864	17	1,508,571	98	52.1	4
Finland	4,207	23	821,970	110	51.2	5
Denmark	6,715	20	1,466,000	99	45.8	6
Austria	5,656	21	1,861,070	87	30.4	7
Germany	32,133	12	10,996,960	31	29.2	8
Italy	16,648	13	6,049,000	45	27.5	9
Switzerland	4,135	24	1,525,270	97	27.1	10
Norway	2,419	28	898,800	107	26.9	11
France	44,332	8	16,986,190	20	26.1	12
Paraguay	33,101	11	13,513,375	26	24.5	13
Mexico	85,654	5	36,338,366	8	23.6	14
Australia	53,660	7	24,398,826	14	22.0	15
Brazil	473,872	2	234,352,649	1	20.2	16
Viet Nam	11,426	15	6,339,400	44	18.0	17
Argentina	96,165	3	54,242,595	6	17.7	18
Hungary	1,516	33	894,000	108	17.0	19
Colombia	42,539	9	29,642,539	12	14.4	20

¹ Total of embryos (IVD + IVP) recorded in 2023

² According to FaoStat 2022 [²]

³ According to cattle herd size, ranked from the largest to the smallest

⁴ Embryos recorded per 10,000 cattle heads

3. Discussion

The number of IVP cattle embryos recorded worldwide has been increasing continuously since 2012, at an average rate of +14.8% per year. Therefore, the +15.8% increase observed in 2023 aligns with general trend seen since 2012. During the period 2012-2019, however, the steep rise in the use of IVEP (+160.7%) was partially balanced by a decrease in the number of IVD embryos collected (-48.3%), limiting the overall growth in totals (+32.2%). After the pandemic, we observed a transitional period (2020-2022) during which the use of superovulation increased (+9.5%), although to a lesser extent than the growth observed for

IVEP (+40.1%). Consequently, the gap between the number of IVP and IVD embryos reported annually continued to widen. With the -6.3% reduction observed in IVD numbers in 2023, however, this difference reached a record fivefold margin (1,876,591 vs. 371,138 for IVP and IVD, respectively).

The growth in the use of IVEP was driven primarily by North America, a region that reported over one million IVP cattle embryos in 2023. Nevertheless, this was a global trend, with eight out of the top 10 countries in the embryo rank reporting more IVP than IVD embryos (USA, Brazil, Argentina, Canada, Mexico, Australia, Colombia, and the Netherlands). Interestingly, only about half of the embryos produced in North America were actually transferred. Therefore, the difference between the total transferred IVP and IVD embryos was smaller (1,284,164 vs. 327,489, respectively; 3.9-fold) than the difference observed between the total number of embryos produced and collected. On the other hand, it is likely that IVP data from South America was underreported, and the actual number of transferred IVP embryos is probably greater than reported here. For instance, the number of ET sheaths were sold in Brazil in 2023 was 119.6% greater than the number of transferred embryos.

The trend toward the adoption of *in vitro* technologies was evident in other aspects of the embryo market. In 2023, 95.0% of the embryos micromanipulated for sexing and 94.6% of those genotyped were IVP. Similarly, exports of IVD cattle embryos decreased (-45.5%), while those of IVP embryos increased significantly (+63.8%). Based on current trends, one can anticipate that IVP embryos will become the main choice for exports in the near future, highlighting the importance of discussing the sanitary restrictions still imposed on such embryos by many countries [3]. It is noteworthy that IVEP also increased in all other species (+62.3% in sheep, +14.9% in horses, and +299.1% in goats compared with 2022). In horses, all exported embryos were IVP, most using ICSI.

This year, the Animal Reproduction Branch of Chinese Association of Animal Science and Veterinary Medicine (ARB-CAAV) reported ET data from China for 2022 and 2023. This is particularly significant given China's relevance in the global livestock industry. China holds the largest sheep and swine inventories worldwide (194,030,298 and 458,078,079 heads, respectively), as well as the second largest goat and fifth largest cattle inventories (132,359,660 and 61,390,129 heads, respectively) [2]. Moreover, China is the world's second-largest economy and has become a powerhouse in science and technology. As such, the country represents a huge potential market for embryo technologies. In fact, the embryo industry was very active in China in the late 1990s and early 2000s, with a peak in 2003, when approximately 60,000 IVD domestic and 130,000 IVP imported cattle embryos were transferred [4]. However, the activity gradually declined thereafter, and data reporting was discontinued for several years. Although some insights into ET activity could be inferred from embryo export data to China, a comprehensive picture of the use of embryo technologies in this country was lacking. The 2022 and 2023 data submitted to the DRC now fill this void, showing notable use of *in vivo* collection and *in vitro* production of cattle embryos in China, albeit not yet on a scale sufficient to influence global trends. Nevertheless, considering China's significant demand for animal protein, further increases in ET activity in the country can be anticipated. This potential growth could position China as an important player in global cattle ET market in the near future.

In sheep, on the other hand, the inclusion of data from China significantly changed the totals in 2023. Up to 2022, the use of IVEP in this species was already increasing but still accounted for less than 2% of the embryos recorded worldwide. The number of sheep IVP embryos reported by China in 2023, however, represents 21.1% of the total embryos recorded and 10.3% of those actually transferred in sheep. In this regard, neither the increase (+62.3%) observed in the total number of IVP embryos nor the decrease (-25.8%) in the number of embryos transferred in 2023 compared with 2022 reflects a general trend. Instead, these figures primarily reflect the activity reported by China during these years. The impact of the inclusion of these data on global totals also underscores the importance of pursuing strategies

to enhance the comprehensiveness of our survey worldwide, particularly for species other than cattle.

4. Acknowledgements

The DRC 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 their volunteer collaboration.

5. References

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Appendix 1: National data collectors in 2023

Region/Country	Collector	Region/Cou ntry	Collector
Africa		Europe	
Rep South Africa	Morne de la Rey, ABS	AETE	H�el�ene Quinton
Asia		Austria	Eva Dachsberger
China	Jianhui Tian (ARB-CAAV)	Belgium	Isabelle Donnay
Vietnam	Joao Viana *, ABS	Czech Republic	Jiri Sichtar
Oceania		Denmark	Henrik Callesen
Australia	Corrie Croton, DAFF, ABS, Vytelle	Estonia	Ants Kavak
New Zealand	Joao Viana *, Vytelle	Finland	Anna Oksa-Pulliainen
North America		France	Serge Lacaze
Canada	Reuben Mapletoft (CETA)	Germany	Hubert Cramer
Mexico	Salvador Romo, ABS	Hungary	Ferenc Flink
United States	Charles Looney, Alvaro Garcia-Guerra, Scott Larsen (AETA)	Italy	Giovanna Lazzari
South & Central America		Latvia	Ilga Sematovica
Argentina (bovine)	Gabriel Bo (SATE)	Lithuania	Rasa Nainiene
Brazil (bovine)	Joao Viana (SBTE)	Netherlands	Anna Van Woundenberg; Erik Mullaart
Brazil (equine)	Marco Alvarenga	Norway	Tjerand Lunde
Brazil (small rum)	Joanna Souza-Fabjan	Poland	Jedrzej Jaskowski
Bolivia	Joao Viana *, ABS	Portugal	Joao Nestor Chagas e Silva
Colombia	Jorge Luis Zambrano, ABS	Romania	Stefan Ciornei
Panama	Luis Nasser	Russian Fed.	Victor Madison
Paraguay	Mar�a Paz Ben�itez Mora, Gabriel Soria	Slovakia	Dalibor Polak
Peru	Marlene Miguel-Gonzales	Slovenia	Janko Mrkun; Aleksandar Plavsic
Uruguay	Joao Viana *, ABS	Spain	Pablo Bermejo
Venezuela	Joao Viana *, ABS	Sweden	Renee B�age
		Switzerland	Andreas Fleisch
		Turkey	Hakan Sagirkaya
		UK	Peter May; Jake Olivier

* Data collected/organized by the Chair