2018 Statistics of embryo production and transfer in domestic farm animals

Embryo industry on a new level: over one million embryos produced *in vitro*

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1. Executive summary

The International Embryo Transfer Society (IETS) Data Retrieval Committee presents the 28th annual report on the data collected globally during 2019 for embryo transfer (ET) activities in 2018. No major change was observed in the number of countries submitting data this year (21%; Table 1). In spite of the efforts of this committee, recovering data from Asia remains a challenge and the lack of numbers from Japan in the past two years certainly contributed to blurry local trends in the embryo industry. On the other hand, we have comprehensive data from most European and American countries where livestock is economically relevant. Thus, the numbers presented in this report are likely to represent the main trends for the world ET activity.

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

Region	Cattle		Other (IVD + IVP)				% countries within region
	IVD	IVP	Horses	Sheep	Goats	Other*	
Africa	2	1	0	1	1	0	3.7% (02/54)
Asia	1	0	0	0	0	0	2.1% (01/48)
Europe	24	14	10	7	2	2	55.3% (26/47)
North America	3	3	3	3	3	0	100.0% (03/03)
Oceania	1	1	0	1	0	0	7.1% (01/14)
South America	5	10	2	2	1	1	27.8% (10/36)
Total	36	29	15	14	7	3	21.3% (43/209)

* Cervids, buffalo

The numbers of the world embryo industry in 2018 for the four most representative farm animal species are summarized in Tables 1 (total embryo production/collection) and 2 (numbers of transferred embryos). Cattle is by far the species in which embryo technologies are mostly used, with 1,499,367 transferrable embryos collected or produced in 2018 (96.7%). There was a relative stabilization in total ET activity in this species compared with 2017 (+0.8%), in contrast with a previous period of consistent growth from 2014 to 2017 (overall +23.4%). The

main trends observed in 2017 were seen again this year: decrease (-5.1%) in the number of *in vivo*-derived (IVD) and increase (+2.6%) in *in vitro*-produced (IVP) embryos.

Over one million IVP bovine embryos were recorded in 2018, accounting for 68.7% of the total. Among the 43 countries with cattle ET data, 29 (67.4%) reported the use of *in vitro* embryo production (IVEP). Although this technology was the main source of embryos in only 18 (41.9%) countries, these countries accounted for 85.7% of all embryos produced worldwide. The predominance of IVP over IVD embryos varied according to region, being more frequent in North and South American countries (11/13, 84.6%) than in Europe (6/25, 24%).

The trend of increasing the use of *in vitro* technologies was not restricted to cattle. Although the majority of embryos from other species are still IVD, the number of IVP embryos recorded increased +675.8% in sheep, +1,241.0% in goats, and +85.6% in horses, leaded by different countries (Spain, South Africa, and Italy, respectively). Another reflect of this trend was a greater increase in the use of embryo sexing and genotyping in IVP than in IVD embryos, compared with the year 2017 (+447.9% and +429.8% vs. +8.3% and -15.6%%; respectively).

The decrease in the number of collected IVD embryos followed the trend observed over the past decade. However, superovulation is still used by 79.0% of the countries reporting ET data, and most of the embryos exported worldwide were IVD (87.9 for bovine and 100.0% for sheep). The majority of IVD embryos were from North America (57.5%) and Europe (30.0%).

Table 2. Total transferrable IVD and IVP embryos in 2018 in cattle, sheep, goats, and horses, according to region.

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	6,651	3,741	0	0	3,325	0	100	660
Asia	162	0	0	0	0	0	0	0
Europe	141,209	61,816	1,395	2,107	3,661	457	227	158
North America	270,187	503,718	1,149	0	2,158	0	8,075	0
Oceania	4,445	11,997	0	0	2,970	0	0	0
South America	47,313	448,128	18,768	346	5,239	55	402	0
Total	**469,967**	**1,029,400**	**21,312**	**2,453**	**17,353**	**512**	**8,804**	**818**

A total of 1,129,041 bovine embryos were transferred in 2018. Most IVP embryos were transferred fresh (73.2%); however, the proportion of frozen IVP embryos transferred in 2018 decreased compared with 2017 (26.8 vs. 33.9%, respectively), breaking a tendency observed since 2013. On the other hand, more IVD frozen-thawed embryos were transferred (60.1%) compared with IVD fresh, with no changes in this percentage compared with last year. In spite of leading IVEP, the proportion of total IVP embryos that were actually transferred in North America was lower than in South America (59.0% vs. 86.9%, respectively) and, thus, South America remains as the region where more IVP embryos are transferred (390,297). In all regions, IVP embryos were transferred predominantly fresh (overall 73.2%).

Table 3. Transfers of IVD and IVP embryos in 2018 in cattle, sheep, goats, and horses, according to region.

Region	Cattle		Horses		Sheep		Goats	
	IVD	IVP	IVD	IVP	IVD	IVP	IVD	IVP
Africa	6,931	1,948	0	0	3,725	0	100	0
Asia	171	0	0	0	0	0	0	0
Europe	125,991	42,843	1,247	762	3,932	303	26	158
North America	204,287	297,094	2,587	0	1,781	0	7,411	0
Oceania	2,682	10,726	0	0	2,762	0	0	0
South America	46,071	390,297	18,661	318	5,310	55	462	0
Total	**386,133**	**742,908**	**22,495**	**1,080**	**17,510**	**358**	**7,999**	**158**

In summary, ET data for the year 2018 demonstrate less dramatic changes, in comparison with the past few years. The world embryo industry reached a new level of circa 1.5 million embryos produced per year, with the number of IVP embryos accounting for 2/3 of the total in cattle, and also increasing in other species. The main movements of ET activity, regarding global distribution, species, livestock sector involved, and use of cryopreservation were shaped by the potentials, flaws, and challenges of IVEP, compared with the collection of IVD embryos.

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 28th annual report showing data on global activities related to *in vivo* and *in vitro* embryo collection and transfer in 2018. The results shown in the present report will be discussed during the Committee meeting, schedule for the next IETS meeting, in New York, NY, USA, and will support further decisions and strategies for the DRC in the following years.

3. Methodology

Data collection followed the standard methodology used in previous reports, as described by Perry (2014). In summary, embryo technology activity was either reported for each country by a national 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 linked to the national embryo transfer/technology association: Argentina (Sociedad Argentina de Tecnologias 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 is submitted by a regional collector on behalf of the Association of Embryo Technology in Europe (AETE). Data was also reported by ET teams or companies working abroad. In a few countries, this was the only source of information of embryo activity. In the case of similar data reported by a local representative, however, data coming from such teams or companies were not used, to avoid double-reporting. The updated 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, according to 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. Detailed country information will be available in the Appendix 2 to 6. Data was also used to build historical series, shown in Figures 2 to 4.

4. Results

Data retrieval

The cooperation with national or regional ET associations has been the most important way to gather comprehensive ET data, what emphasize their importance for the IETS. The countries with well-established ET societies, particularly within Europe and the Americas, have ensured consistent ET records over the past years. In addition, individual local collectors as well as ET teams or companies that report data directly to this committee were decisive to recover data from countries without an organized ET society and, thus, to fill-in the gaps in our survey. In 2018, we obtained ET records from 43 countries (Figure 1), including from the majority of countries in Europe (26/47, 55.3%) and from all North America (3/3, 100%). In Central and South America, we obtained records from 27.8% (10/36) of the countries, but that includes those among the most important in livestock production in this region.

Data from Africa and Oceania is clearly underestimated, although representative of the regional trends. New Zealand, for example, has a well-known ET activity, but reports no data. Nevertheless, the main problem remains the gathering of data from Asia. In this regard, the lack of records from Japan in the past two years was a major problem, as this country had the most active embryo industry within this region in recent past. Still, the countries reporting ET data in 2018 accounted for approximately 41.9% of the world cattle population in 2017 (FAO, 2019) and included nine of the top 10 meat-producing countries and five of the top 10 fresh dairy producers. Thus, the numbers presented in this report are probably representative of the embryo industry activity worldwide.

Figure 1. World political map showing the countries that submitted 2018 ET data

4.1 Embryo industry in numbers

4.1.1 Cattle, IVD

In 2018, a total of 1,499,367 transferrable embryos were collected or produced, which represents a relative stabilization compared with 2017 (+0.8%). In regard to type of embryo, IVD and IVP embryos represented 31.3% (469,967) and 68.7% (1,029,400) of the total, respectively.

Table 4. Collection of bovine IVD embryos per region

Region/ Country	Flushes			Collected					
				Ova			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	13	1,526	1,548	148	7,493	7,748	85	6,507	6,651
Asia	42	1	43	239	6	245	156	6	162
Europe	18,425	4,929	23,354	172,950	42,139	215,089	110,865	30,344	141,209
N America	16,069	25,904	41,973	157,462	319,186	476,648	91,693	178,494	270,187
Oceania	0	901	901	0	4,445	4,445	0	4,445	4,445

S America	3,248	5,009	8,257	24,198	44,965	69,163	20,167	27,146	47,313
Total	**37,797**	**38,270**	**76,076**	**354,997**	**418,234**	**773,338**	**222,966**	**246,942**	**469,967**

From the 42 countries reporting ET data, 34 (79.0%) informed the collection of IVD bovine embryos. The number of flushes, ova, and transferrable embryos collected in 2018 according to region is shown in Table 4. The number of IVD embryos decreased (469,967 vs. 495,054; -5.1%), compared with 2017, following the tendency observed in the past few years. Interestingly, a non-proportional reduction in the number of flushes (-1.9%) resulted in a slight reduction in the average number of ova and transferrable embryos per flush (10.2 and 6.2 vs. 10.6 and 6.4 in 2017, respectively). The majority of IVD embryos were from North America (57.5%), leaded by the United States (205,445; 43.7% of total), followed by Europe (30.0%). These two regions, however, differ in the proportion of collections according to livestock sector. In North America, 66.1% of the embryos are from beef breeds, whereas in Europe 78.5% are from dairy breeds.

Only 6.8% of the IVD embryo donors were inseminated with sex-sorted semen, the vast majority were from dairy breeds (95.3%). The greatest proportions of use of sex-sorted semen were observed in Poland and Spain (51.3% and 51.0%, respectively).

The transfer of IVD embryos in 2018 is shown in Table 5. The proportion of transfers of fresh vs. frozen-thawed embryos (60.1% vs. 39.9%, respectively) were identical to the observed in 2017, as well as the proportion of total viable embryos that were actually transferred (82.2%). Transfers of fresh embryos were proportionally more frequent in regions with low ET activity, such as Africa, Asia, and Oceania. In Europe, North, and South America, the number of transfers of frozen-thawed embryos was always greater than fresh embryos.

Table 5. Transfer of bovine IVD embryos by region

Region/ Country	Fresh			Frozen domestic			Frozen imported			Total ET
	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	Dairy	Beef	Unsorted	
Africa	65	3,159	0	34	1,574	0	0	2,099	0	**6,931**
Asia	146	6	0	19	0	0	0	0	0	**171**
Europe	36,858	5,415	9,909	50,181	19,177	813	2,634	847	157	**125,991**
N America	32,851	42,920	139	35,489	92,406	0	61	421	0	**204,287**
Oceania	0	2,241	0	0	261	0	0	180	0	**2,682**
S America	9,886	10,347	0	10,218	15,367	0	141	112	0	**46,071**
Total	**79,806**	**64,088**	**10,048**	**95,941**	**128,785**	**813**	**2,836**	**3,659**	**157**	**386,133**

4.1.2 Cattle, IVP

The number of countries reporting IVP embryos increased from 25 in 2017 to 29 in 2018. In 18 of those (41.9%) IVEP was the main source of embryos. These countries accounted for 85.7% of all cattle embryos produced worldwide. The production of embryos *in vitro* in 2018 is shown in Tables 6 (OPU-collected oocytes) and 7 (abattoir-derived oocytes).

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

Region/	Donors			Oocytes			Transferrable embryos		
Country	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa	0	621	621	0	18,486	18,486	0	3,741	3,741
Asia	0	0	0	0	0	0	0	0	0
Europe	24,809	4,432	29,241	206,510	36,529	243,039	48,875	11,502	60,377
N America	91,366	27,044	118,410	1,402,896	601,595	2,004,491	311,056	186,455	497,511
Oceania	0	2,056	2,056	0	35,767	35,767	0	11,997	11,997
S America	43,062	35,460	78,522	563,151	693,405	1,256,556	209,286	235,251	444,537
Total	159,237	69,613	228,850	2,172,557	1,385,782	3,558,339	569,217	448,946	1,018,163

The increase in the number of IVP embryos (+2.6%) from 2017 to 2018 was much less dramatic than the rate observed from 2016 to 2017 (+48.9%), but still enough to reach a seven-digit number in 2018, when 1,029,400 IVP embryos were recorded. Once again, the USA was the country with the greatest number of IVP embryos, which increased this year (451,661 vs. 428,878 in 2017, +5.3%). In contrast, numbers have stabilized in Brazil (345,126 vs. 345,528 in 2017, -0.1%), increasing the difference between the two countries. Both in USA and in Brazil, most IVP embryos come from dairy than from beef breeds (53.3% and 62.3%; respectively).

The use of FSH stimulation before ovum pick-up (OPU) was applied mainly in Europe (48.1%) and North America (66.9%). In Canada, 100% of OPUs were preceded by ovarian stimulation. OPU remains the main source of oocytes for *in vitro* fertilization, accounting for 98.9% of IVP embryos, whereas the number of embryos produced using abattoir-derived oocytes decreased in 2018 (11,237 vs. 11,756; -4.5%).

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

Region/	Donors			Oocytes			Transferrable embryos		
Country	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	190	1,212	1,402	3,256	6,434	9,690	975	464	1,439
N America	12	10	22	1,182	18,217	19,399	402	5,805	6,207
Oceania	0	0	0	0	0	0	0	0	0
S America	38	887	925	190	14,514	14,704	31	3,560	3,591
Total	240	2,109	2,349	4,628	39,165	43,793	1,408	9,829	11,237

The number of transfers of IVP embryos in 2018 is shown in Table 8. As observed in 2017, the proportion of the total IVP embryos that were actually transferred in North America was lower than in South America (59.0% vs. 86.9%, respectively). Therefore, in spite of the difference in the number of embryos produced, Brazil remains as the country with the greatest number of transfers of IVP embryos (275,683 vs. 260,193 in the USA). In all regions, IVP embryos were transferred predominantly fresh (overall mean 73.2%).

Table 8. Transfer of bovine IVP embryos by region

Region/ Country	Embryos transferred							
	OPU				Abattoir			
	Fresh	Frozen		Total	Fresh	Frozen		Total
		Domestic	Foreign			Domestic	Foreign	
Africa	1,611	337	0	1,948	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Europe	22,343	18,599	1,555	42,497	61	285	0	346
N America	201,322	95,431	245	296,998	96	0	0	96
Oceania	10,046	680	0	10,726	0	0	0	0
S America	306,293	81,540	0	387,833	2,343	121	0	2,464
Total	541,615	196,587	1,800	740,002	2,500	406	0	2,906

Data of embryos micro-manipulated for sexing or genotyping in 2018 is shown in Table 11. Changes in numbers of micro-manipulated embryos seems to follow the general trends observed in the embryo industry. There was a small variation in the number of IVD sexed (+8.3%) or genotyped (-15.6%) embryos, contrasting with the substantial increase in micromanipulation of IVP embryos (+447.9% and +429.8%, respectively). Only countries from Europe and North America reported data from micromanipulated embryos, so it is likely that these numbers may be underestimated.

Table 9. Micro-manipulation of bovine embryos for sexing and/or genotyping

Country	Sexed		Genotyped	
	IVD	IVP	IVD	IVP
Canada	420	6,114	0	6,110
Finland	0	33	38	33
France	3,054	0	1,642	0
Germany	0	0	310	55
Netherlands	0	0	101	2,708

United States	791	0	373	0
Total	4,265	6,147	2,464	8,906

4.1.3 Other species

The numbers of IVD and IVP embryos reported in 2018 in species other than cattle are shown in Tables 10 (sheep), 11 (goats), 12 (horses) and 13 (cervids, buffalo).

Table 10. Sheep: IVD and IVP embryo collections and transfers

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Africa											
S Africa	505	3,325	2,979	746	0	0	0	0	0	0	0
Total	505	3,325	2,979	746	0	0	0	0	0	0	0
Europe											
France	7	25	0	0	0	0	0	0	0	0	0
Hungary	5	39	0	0	45	0	0	0	0	0	0
Italy	12	58	58	0	0	0	0	0	0	0	0
Serbia	3	16	0	0	0	0	0	0	0	0	0
Spain	56	160	34	0	0	39	909	457	303	0	0
Sweden	20	67	0	67	365	0	0	0	0	0	0
UK	537	3.296	3,247	116	0	0	0	0	0	0	0
Total	640	3,661	3,339	183	410	39	909	457	303	0	0
N America											
Canada	17	99	17	155	0	0	0	0	0	0	0
Mexico	164	1,148	850	25	144	0	0	0	0	0	0
USA	193	911	577	9	4	0	0	0	0	0	0
Total	374	2,158	1,444	189	148	0	0	0	0	0	0
Oceania											
Australia	495	2,970	2,617	145	0	0	0	0	0	0	0

Total	495	2,970	2,617	145	0	0	0	0	0	0	0
S America											
Argentina	112	431	402	0	100	0	0	0	0	0	0
Brazil	618	4,808	3,906	902	0	11	138	55	55	0	0
Total	730	5,239	4,308	902	100	11	138	55	55	0	0
Grand Total	**2,744**	**17,353**	**14,687**	**2,165**	**658**	**50**	**1,047**	**512**	**358**	**0**	**0**

In 2018, a small reduction in the number of embryos produced in sheep (18,400 vs. 18,718; -1.7%) was detected. However, the number of countries reporting data in this species increased (14 vs. 9 in 2017), so data in Table 10 is now stratified by region, similar to the model adopted for cattle. There was also a noticeable increase in the number of IVP embryos (512 vs. 66 in 2017, +675.8%), with 358 transfers. Brazil was the country with the highest number of IVD embryos (4,808), thanks for the effort of the local collector in obtaining comprehensive data. Spain was the leader in the production of embryos *in vitro* (457).

The goat embryo industry had also developed significantly. In 2018, more countries (n=7) reported data and a greater number of IVD and IVP embryos were recorded, compared with 2017 (8,804 vs. 3,975 [+121.5%] and 818 vs. 61 [+1,241.0%], respectively). The USA reported most of the IVD embryos (7,541; 85.7% of the total), but South Africa recorded more IVP embryos (660).

Table 11. Goats: IVD and IVP embryo collections and transfers

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Africa											
South Africa	0	100	100	0	0	20	110	660	0	0	0
Total	0	100	100	0	0	20	110	660	0	0	0
Europe											
Spain	25	201	0	0	0	6	1,710	158	108	50	0
UK	3	26	26	0	0	0	0	0	0	0	0
Total	28	227	26	0	0	6	1,710	158	108	50	0
N America											
Canada	18	40	8	4	0	0	0	0	0	0	0
Mexico	76	494	425	45	85	0	0	0	0	0	0

USA	1,052	7,541	5,672	1,172	0	0	0	0	0	0	0
Total	1,146	8,075	6,105	1,221	85	0	0	0	0	0	0
S America											
Brazil	104	402	223	239	0	0	0	0	0	0	0
Total	104	402	223	239	0	0	0	0	0	0	0
Grand Total	**1,278**	**8,804**	**6,454**	**1,460**	**85**	**26**	**1,820**	**818**	**108**	**50**	**0**

The horse embryo industry also increased, although variations were lower than those for small ruminants. More countries reported data (n=15; +25%), and more IVD (21,312; +2.4%) and IVP (2,453; +85.6%) embryos were recorded, compared with 2017. In 2018, IVP embryos accounted for 11.5% of all horse embryos, almost twice as much as last year (6.4%). Brazil and Italy remain the countries that record more IVD and IVP horse embryos (18,764 and 1,431; respectively).

Table 12. Horses: IVD and IVP embryo collections and transfers

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	1,315	736	818	0	0	0	0	0	10	0	0
Italy	309	211	0	0	0	1,062	12,605	1,431	65	352	0
Netherlands	281	157	160	0	0	456	5,933	664	38	20	273
Poland	5	4	2	0	0	0	0	0	0	0	0
Portugal	211	84	76	8	0	0	0	0	0	0	0
Russian Fed.	26	18	8	3	0	0	0	0	0	0	0
Spain	170	93	91	0	0	0	0	0	0	0	0
Sweden	23	15	15	0	0	0	0	0	0	0	0
Switzerland	90	42	22	1	0	68	191	12	0	4	0
UK	65	35	43	0	0	0	0	0	0	0	0
Total	2,495	1,395	1,235	12	0	1,586	18,729	2,107	113	376	273
N America											
Canada	37	15	15	0	0	0	0	0	0	0	0
Mexico	75	29	29	0	0	0	0	0	0	0	0
USA	1,816	1,105	1,952	591	0	0	0	0	0	0	0
Total	1,928	1,149	1,996	591	0	0	0	0	0	0	0
S America											
Brazil	29,152	18,764	18,657	0	0	128	1,150	346	318	0	0
Ecuador	5	4	4	0	0	0	0	0	0	0	0
Total	29,157	18,768	18,661	0	0	128	1,150	346	318	0	0
Grand Total	**33,580**	**21,312**	**21,892**	**603**	**0**	**1,714**	**19,879**	**2,453**	**431**	**376**	**273**

Unfortunately, in 2018 we had no record of ET activity in swine or camelids and only Argentina recorded embryos from cervids, which probably does not reflect the real scenario. ET in buffalo was reported by Romania (IVD) and Italy (IVP) only.

Table 13. Other species: IVD and IVP embryo collections and transfers

Region/ Country	IVD Embryos					IVP embryos					
	Flushes	Embryos	Embryo transfer			Donors	Oocytes	Embryos	Embryo transfer		
			Fresh	Frozen					Fresh	Frozen	
				Domestic	Foreign					Domestic	Foreign
Cervids											
Argentina	8	38	0	0	0	0	0	0	0	0	0
Buffalo											
Italy	0	0	0	0	0	2	49	21	27	0	0
Romania	3	6	0	0	0	0	0	0	0	0	0
Total	3	6	0	0	0	2	49	21	27	0	0

4.1.4 Exports

The number of embryos exported are shown in Table 14. In 2018, a total of 32,746 bovine embryos (IVD+IVP) were exported, with no significant change compared with 2017 (-0.3%). On the other hand, exports of sheep embryos increased 34.3%, leaded by Canada. Most of the exported embryos are IVD (87.9 for bovine and 100% for sheep).

Table 14. Countries exporting embryos

Region/ Country	Bovine					Sheep
	IVD			IVP		IVD
	Dairy	Beef	Unsorted	OPU	Abattoir	
Africa						
Rep South Africa	0	253	0	0	0	124
Total	0	253	0	0	0	124
Europe						
Austria	40	9	0	0	0	0
Belgium	20	900	0	0	0	0
Denmark	36	0	0	0	0	0
France	637	351	0	88	0	0
Germany	81	0	0	0	0	0
Italy	0	0	0	0	0	0

Norway	18	38	0	0	0	0
Spain	50	0	0	0	0	0
Switzerland	61	0	0	0	0	0
United Kingdom	0	0	63	0	0	0
Total	943	1,298	63	88	0	0
N America						
Canada	4,524	4,076	0	274	0	969
United States	11,535	3,119	0	3,503	0	0
Total	16,059	7,195	0	3,777	0	969
Oceania						
Australia	0	574	0	0	0	208
Total	0	574	0	0	0	208
S America						
Argentina	0	2,301	0	97	0	0
Total	0	2,301	0	97	0	0
Grand Total	**17,002**	**11,621**	**63**	**3,962**	**0**	**1,301**

4.2 Historical series and trends

The historical series of cattle embryo production (IVD, IVP, and total) in the past 20 years is shown in Figure 2. The numbers of IVP embryos have increased uninterruptedly since 2012, at an average rate of 15.8% per year, a two-fold rise since then, boosted mainly by the growth on the North American embryo industry after 2016 (Figure 3). In 2018, over one million IVP embryos were reported, a new world record. The substantial increase in IVEP in the past decade, however, was partially balanced by a smaller but consistent decrease in the collection of IVD embryos in the past 10 years (average -4.1% per year, Figure 4). As a result, total embryo production did not grow as fast as the records of IVP embryos, remaining for a decade at circa 1.2 million embryos. In the past two years, however, IVEP grow has pushed the total numbers of the world embryo industry to a new level of 1.5 million embryos.

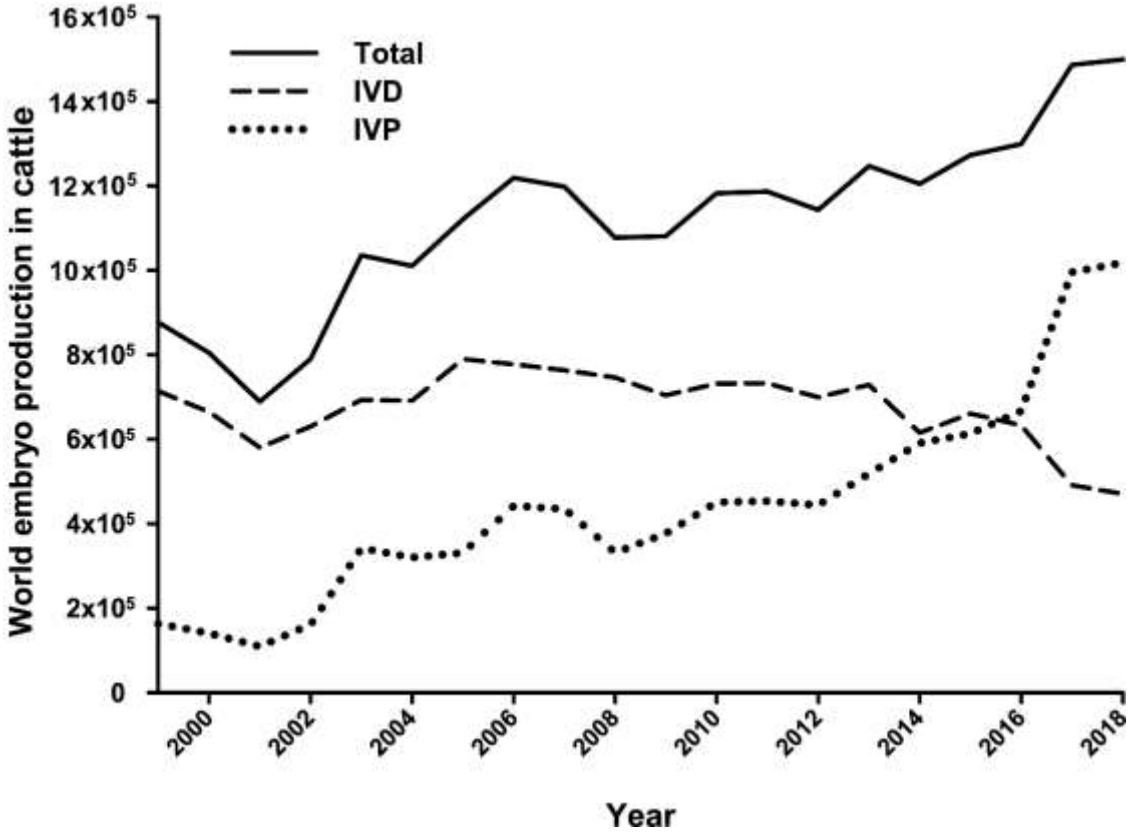

Figure 2. Number of bovine embryos (IVD, IVP, and total) recorded in the period 1999-2018

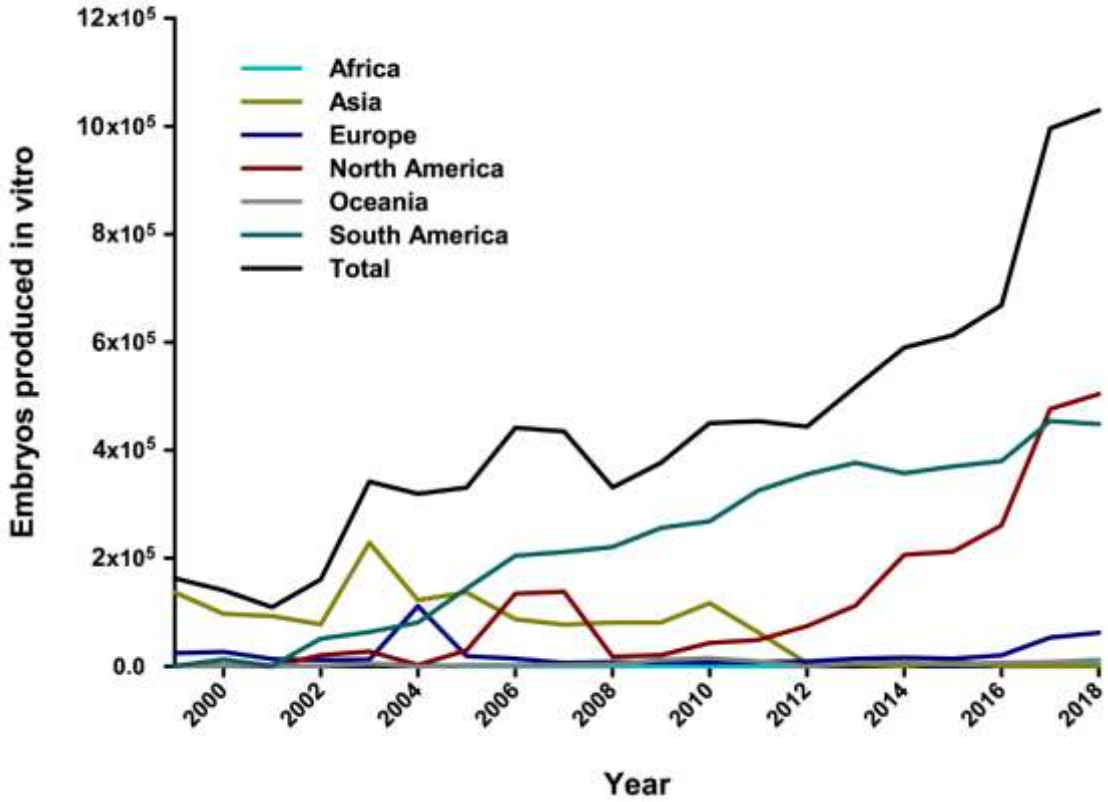

Figure 3. Number of IVP bovine embryos in the period of 1999-2018, by continent

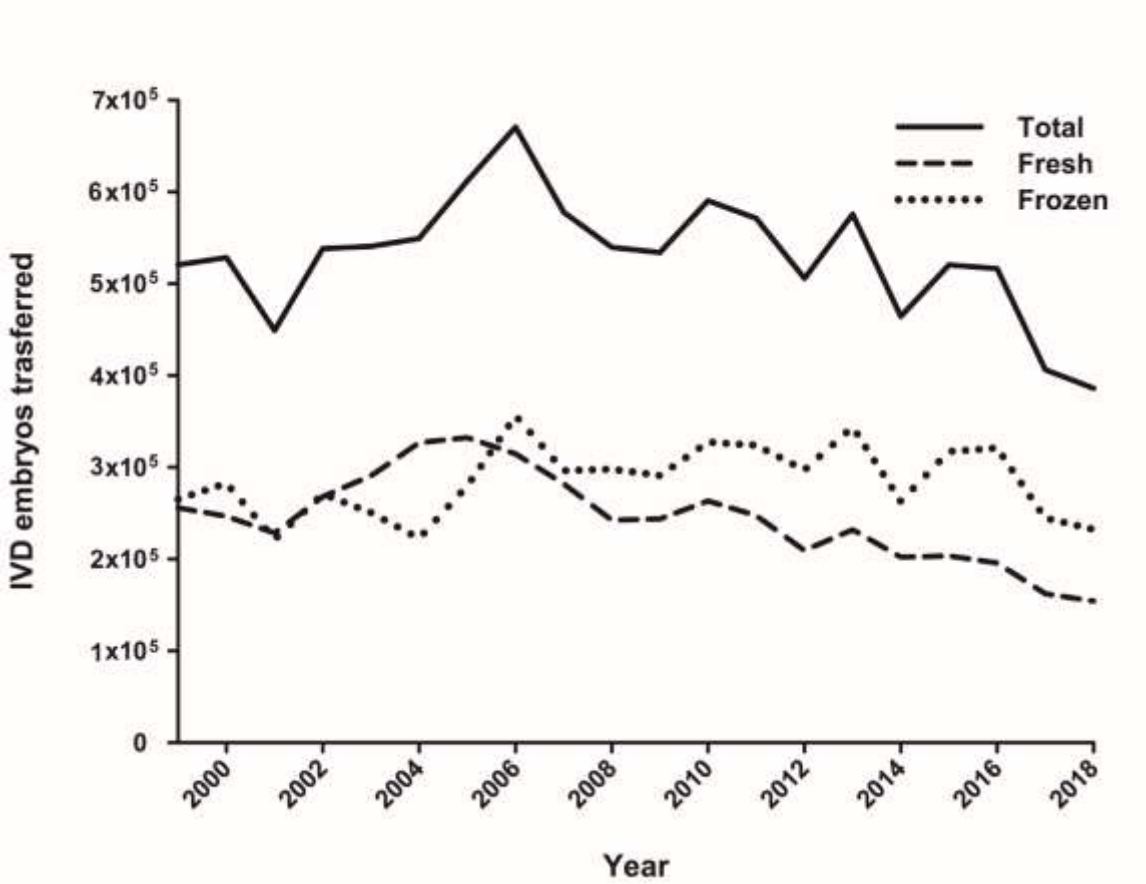

Figure 4. Number of total, fresh and frozen *in vivo* bovine embryo transfers in the period 1999-2018.

5. Discussion

The figures of the world embryo industry in 2018 are in aligned with the trends reported in the past few years and the main one is the progressive adoption of *in vitro* technologies worldwide. The number of IVP embryos passed those of IVD embryos in 2017 and, in 2018, reached over one million records, accounting for almost 70% of the total. The exponential growth of IVEP in North America in the last five years was key to reach this milestone, as the Brazilian numbers have stagnated (-0.1% this year) after the 2014-2016 economic crisis and recession.

It is reasonable to expect that IVEP would develop at faster rates in countries with large herds and where livestock is an important sector of the economy, because the infrastructure required represents high fixed-costs. Thus, the scale effect is determinant for the economic viability

of the technique. Coherently, the two countries with greatest IVEP (Brazil and USA) are also those with the two largest commercial cattle herds in the world. Nevertheless, it is noticeable that an increasing proportion of countries in all regions (overall 41.9% in 2018) has IVEP as the main source of transferable cattle embryos. The increase in the use of *in vitro* technologies was also not restricted to cattle. Although the majority of embryos from other species are still IVD, the number of IVP embryos increased +675.8% in sheep, +1,241.0% in goats, and +85.6% in horses. The features of IVEP may also have favored the adoption of other technologies that requires embryo micromanipulation, explaining the different tendencies observed for sexing and genotyping in IVD vs IVP embryos (+8.3% and -15.6%% vs. +447.9% and +429.8%; respectively). In this regard, the expansion in the number of countries adopting IVEP may have created a platform for the further development of other embryo technologies.

The rising of IVEP worldwide in the past decade was associated with a decrease in the numbers of collected IVD embryos. However, changes were not proportional and the positive balance resulted in the increase in total global numbers (+38.7% from 2009 to 2018). In fact, the adoption of IVEP usually causes a remarkable rise in the embryo industry numbers, as previously observed in Brazil, Argentina and, more recently, the USA. The relatively slow growth observed in global numbers in the beginning of the past decade can be partially explained by the decline in ET records from Asia after 2010, where lack of consistent data impairs a clear interpretation of the current trends. For instance, there is no data from Peoples Republic of China since 2008 and from Japan since 2017 (Thibier 2009, Viana 2018). These two countries were leaders of the Asian embryo industry in the early 2000s'. In 2006, for example, this region accounted for 27.4% and 28.2% of the world IVD and IVP records, respectively (Thibier 2007). The Japanese Embryo Transfer Society is currently discussing how to resume data retrieval in the country.

The balance between the trends for IVP and IVD embryos, mainly in the last two years, allowed world ET numbers to reach approximately 1.5 million embryos recorded in a year. This clearly demonstrates that the worldwide growth of IVEP involved the emergence of new potential markets. On the other hand, in spite of the consistent inclination for the reduction in the collection of IVD embryos over the years, more frozen IVD embryos were transferred in the past 10 years than in the decade before (2,960,811 [58.4% of total] from 2009 to 2018 vs. 2,741,023 [49.6% of total] from 1999 to 2008, respectively), as shown in Figure 4. This can be a reflex of the lower proportion of transfers of frozen-thawed IVP embryos (26.8%). Thus, it is likely that collection of IVD embryos has been used as an alternative to overcome the low cryotolerance of IVP embryos, in situations requiring cryopreservation. Coherently, the number of exported IVD embryos increased (+7.8%), whereas IVP embryo exports decreased (-35.4%).

This technological shift from IVD to IVP embryos occurred in a manner that affected different aspects of ET activity, such as global distribution, species, livestock sector involved, use of sex-sorted semen, cryopreservation, micromanipulation etc. The possible forecast for the evolution of the world embryo industry in the years to come is positive. In this regard, these recent changes also highlight the importance of data retrieval as a strategy to objectively study and understand the potentials and technical limitations of in vitro technologies, based on the large-scale use in a commercial scenario. The correct identification of technological gaps and opportunities is crucial to define research focus and public policies.

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 Siqueira for reviewing this report.

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Appendix 1: National data collectors in 2018

Region/Country	Collector	Region/Country	Collector
Africa		**Europe**	
Namibia	Morne de la Rey	AETE	Marja Mikkola
Rep South Africa	Morne de la Rey	Austria	Friedrich Führer
		Belgium	Peter Vercauteren, Isabelle Donnay
Asia		Bosnia Herzegovina	Teodor Markovic
Israel	Amir Shifman, Yoel Zeron	Czech Republic	Pavel Bucek
		Denmark	Henrik Callesen
Central America		Estonia	Jevgeni Kurykin
Panama	Luis Nasser	Finland	Seija Vahtiala
Dominican Rep	Joao Viana *	France	Serge Lacaze
		Germany	Hubert Cramer
North America		Greece	Foteini Samartzi
Canada	Reuben Mapletoft (CETA)	Hungary	Istvan Pentek
Mexico	Salvador Romo	Ireland	Patrick Lonergan
United States	Daniela Demetrio (AETA)	Italy	Giovanna Lazzari
		Latvia	Vita Antane
South America		Lithuania	Raisa Nainiene
Argentina	Gabriel Bo	The Netherlands	Helga Flapper, Hilde Aardema
Brazil (bovine)	Joao Viana	Macedonia	Toni Dovenski
Brazil (equine)	Marco Alvarenga	Norway	Marja Mikkola
Brazil (small rum)	Jeferson Fonseca, Joanna Souza-Fafjan	Poland	Jędrzej Jaśkowski
Bolivia	Joao Viana *	Portugal	João Nestor Chagas e Silva
Ecuador	Andres Vera Cedeño, Antonio Murillo	Romania	Stefan Ciornei
Paraguay	María Paz Benítez Mora, Gabriel Soria	Russian Federation	Denis Knurow, Viktor Madison

Peru	Edwin Mellisho	Serbia	Aleksandar Milovanovic
Uruguay	Joao Viana *	Slovakia	Jozef Bires, Dalibor Polak
Venezuela	Joao Viana *	Slovenia	Janko Mrkun
		Spain	Daniel Martinez Bello
Oceania		Sweden	Renée Båge
Australia	Cedric M Wise, Genstock WA, IVB	Switzerland	Rainer Saner
		Turkey	Ebru Emsen
		Ukraine	Viktor Madison
		United Kingdom	Roger Sturmey, Brian Graham

* Data collected/organized by the Chair

Appendix 2: Bovine *in-vivo* derived embryo collection by region and countries

Region/ Country	Flushes						Collected					
	Conventional semen			Sexed semen			Total ova			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Africa												
Namibia	0	9	9	0	0	0	0	107	107	0	59	59
Rep South Africa	13	1,495	1,517	0	22	22	148	7,386	7,641	85	6,448	6,592
Asia												
Israel	41	1	42	1	0	1	239	6	245	156	6	162
Europe												
Austria	335	17	352	11	1	12	3,357	95	3,452	2,488	138	2,626
Belgium	121	875	996	8	0	8	813	5,656	6,469	543	4,198	4,741
Bosnia Herzegovina	0	1	1	0	0	0	0	5	5	0	5	5
Denmark	716	54	770	0	0	0	6,179	593	6,772	4,161	392	4,553
Finland	431	3	434	55	0	55	4,007	24	4,031	2,714	4	2,718
France	4,497	1,242	5,739	1,053	94	1,147	50,792	13,825	64,617	29,275	7,494	36,769
Germany	3,166	464	3,630	0	0	0	31,472	4,654	36,126	21,100	2,499	23,599
Hungary	7	36	43	11	6	17	124	385	509	116	255	371
Ireland	664	0	664	0	0	0	8,190	0	8,190	3,904	0	3,904
Italy	2,432	150	2,582	0	0	0	28,397	1,575	29,972	19,418	1,083	20,501
Latvia	11	0	11	0	0	0	52	0	52	43	0	43
Netherlands	2,735	0	2,735	16	0	16	20,847	0	20,847	15,675	0	15,675
Norway	87	11	98	0	0	0	888	155	1,043	586	54	640
Poland	131	0	131	138	0	138	2,193	0	2,193	1,493	0	1,493
Portugal	60	10	70	50	0	50	572	103	675	352	38	390
Romania	9	0	9	0	0	0	48	0	48	40	0	40
Russian Fed,	109	1,530	1,639	442	4	446	5,205	13,143	18,348	2,682	11,416	14,098
Serbia	5	0	5	0	0	0	22	0	22	14	0	14
Slovenia	12	0	12	2	0	2	52	0	52	26	0	26
Spain	102	272	374	374	15	389	4,030	1,382	5,412	2,626	2,002	4,628
Sweden	127	3	130	0	0	0	864	4	868	562	2	564
Switzerland	212	16	228	147	1	148	3,615	149	3,764	2,129	67	2,196
Ukraine	10	8	18	8	4	12	261	175	436	209	125	334
United Kingdom	116	112	228	15	0	15	970	216	1,186	709	572	1,281
N America												
Canada	3,278	3,333	6,611	2,443	66	2,509	61,918	43,866	105,784	36,628	23,077	59,705
Mexico	55	993	1,048	0	2	2	331	4,899	5,230	244	4,793	5,037
United States	10,293	21,510	31,803	0	0	0	95,213	270,421	365,634	54,821	150,624	205,445
Oceania												
Australia	0	901	901	0	0	0	0	4,445	4,445	0	4,445	4,445
S America												
Argentina	311	3,476	3,787	130	11	141	3,626	36,761	40,387	2,301	19,209	21,510
Brazil	2,615	1,108	3,723	0	0	0	20,380	7,205	27,585	17,154	6,065	23,219
Ecuador	25	150	175	25	15	40	50	750	800	35	450	485
Paraguay	0	0	0	0	0	0	0	0	0	0	0	0
Peru	102	244	346	40	5	45	142	249	391	677	1,422	2,099

Appendix 3: Bovine *in-vivo* derived embryos transferred by region and countries

Region/ Country	Fresh embryos				Frozen domestic embryos				Frozen imported embryos			
	Dairy	Beef	Unsorted	Total	Dairy	Beef	Unsorted	Total	Dairy	Beef	Unsorted	Total
Africa												
Namibia	0	37	0	37	0	19	0	19	0	147	0	147
Rep South Africa	65	3,122	0	3,187	34	1,555	0	1,589	0	1,952	0	1,952
Asia												
Israel	146	6	0	152	19	0	0	19	0	0	0	0
Europe												
Austria	1,000	14	0	1,014	1,402	90	0	1,492	15	13	0	28
Belgium	111	614	0	725	451	2,295	0	2,746	578	16	0	594
Denmark	2,386	92	0	2,478	1,102	96	0	1,198	0	0	0	0
Finland	789	4	0	793	1,938	23	0	1,961	165	50	0	215
France	14,604	2,344	43	16,991	13,153	4,333	90	17,576	654	170	12	836
Germany	8,983	689	0	9,672	11,680	1,246	0	12,926	0	0	0	0
Greece	0	0	0	0	0	0	0	0	7	0	0	7
Hungary	60	29	0	89	58	129	0	187	0	0	0	0
Ireland	1,565	0	0	1,565	1,904	0	0	1,904	0	0	0	0
Italy	0	0	7,750	7,750	0	0	0	0	0	0	0	0
Netherlands	4,381	0	1,634	6,015	14,332	0	0	14,332	0	0	0	0
Norway	31	15	0	46	75	61	0	136	143	52	0	195
Poland	667	0	0	667	705	0	0	705	438	0	0	438
Portugal	87	14	0	101	423	23	0	446	0	17	0	17
Romania	23	0	0	23	17	0	0	17	0	46	0	46
Russian Federation	220	885	0	1,105	1,005	10,072	0	11,077	91	105	0	196
Serbia	5	0	0	5	0	0	0	0	7	0	0	7
Slovenia	24	0	0	24	2	0	0	2	0	4	0	4
Spain	1,130	570	0	1,700	1,005	404	0	1,409	110	4	0	114
Sweden	0	0	142	142	0	0	396	396	0	0	103	103
Switzerland	729	3	0	732	810	38	0	848	422	21	0	443
Ukraine	12	61	0	73	74	58	0	132	0	0	0	0
United Kingdom	51	81	340	472	45	309	327	681	4	349	42	395
N America												
Canada	12,009	2,905	0	14,914	16,895	9,755	0	26,650	61	208	0	269
Mexico	0	2,399	139	2,538	45	1,502	0	1,547	0	213	0	213
United States	20,842	37,616	0	58,458	18,549	81,149	0	99,698	0	0	0	0
Oceania												
Australia	0	2,241	0	2,241	0	261	0	261	0	180	0	180
S America												
Argentina	1,467	6,655	0	8,122	909	11,691	0	12,600	104	42	0	146
Brazil	7,888	3,097	0	10,985	9,094	2,729	0	11,823	0	0	0	0
Ecuador	477	500	0	977	200	922	0	1,122	0	0	0	0
Paraguay	0	0	0	0	0	0	0	0	0	0	0	0
Peru	54	95	0	149	15	25	0	40	37	70	0	107

Appendix 4: Bovine OPU-IVEP by region and countries

Region/ Country	Donor preparation					Oocytes					Transferrable embryos				
	Non-stimulated		Stimulated			Non-stimulated		Stimulated			Non-stimulated		Stimulated		
	Dairy	Beef	Dairy	Beef	Total	Dairy	Beef	Dairy	Beef	Total	Dairy	Beef	Dairy	Beef	Total
Africa															
Rep South Africa	0	621	0	0	621	0	18,486	0	0	18486	0	3,741	0	0	3741
Centr America															
Dominican Rep	0	305	0	0	305	0	6,093	0	0	6093	0	1,828	0	0	1828
Panama	315	334	0	0	649	11,262	15,883	0	0	27,145	2,276	2,886	0	0	5,162
Europe															
Estonia	0	0	0	8	8	0	0	0	74	74	0	0	0	24	24
Finland	368	0	315	0	683	1,809	0	2,946	0	4,755	67	0	385	0	452
France	219	0	357	46	622	924	0	3,928	456	5308	214	0	831	166	1,211
Germany	809	20	0	0	829	11,844	337	0	0	12,181	2,621	89	0	0	2,710
Italy	119	0	0	0	119	1,327	0	0	0	1,327	188	0	0	0	188
Netherlands	779	0	9,750	0	10,529	11,300	0	104,103	0	115,403	2,502	0	27,300	0	29,802
Poland	14	0	33	0	47	112	0	324	0	436	62	0	128	0	190
Romania	0	0	4	0	4	0	0	5	0	5	0	0	1	0	1
Russian Fed,	11,882	4,290	0	0	16,172	66,073	35,189	0	0	101,262	14,220	10,984	0	0	25,204
Serbia	18	0	23	0	41	76	0	128	0	204	28	0	32	0	60
Spain	0	68	50	0	118	0	473	770	0	1243	0	239	151	0	390
Switzerland	69	0	0	0	69	841	0	0	0	841	145	0	0	0	145
N America															
Canada	0	0	4,466	464	4,930	0	0	50,435	8,368	58,803	0	0	20,820	3,950	49,540
Mexico	2,095	2,558	0	0	4,653	39,567	62,663	0	0	102,230	9,352	17,361	0	0	26,713
United States	54,515	3,789	30,290	20,233	108,827	838,355	78,203	474,539	452,361	1,843,458	117,237	20,675	163,647	144,469	754,144
Oceania															
Australia	0	2,056	0	0	2056	0	35,767	0	0	35767	0	11,997	0	0	11997
S America															
Argentina	1,535	5,922	8	161	7,626	32,338	136,024	138	1,267	169,767	5,523	27,752	26	307	33,941
Brazil	38,348	21,290	0	0	59,638	460,180	383,238	0	0	843,418	184,072	157,511	0	0	341,583
Bolivia	579	0	0	0	579	11,587	0	0	0	11,587	3,476	0	0	0	3,476
Ecuador	245	173	0	10	428	7,005	6,113	0	150	13,268	1,720	1,544	0	33	3,330
Paraguay	129	6,343	0	0	6,472	2,589	126,864	0	0	129,453	777	38,059	0	0	38,836
Peru	0	0	0	45	45	0	0	0	225	225	0	0	0	67	134
Uruguay	1,318	0	0	0	1,318	26,353	0	0	0	26,353	7,906	0	0	0	7,906
Venezuela	585	877	0	0	1,462	11,699	17,548	0	0	29,247	3,510	5,264	0	0	8,774

Appendix 5: Bovine IVEP using slaughterhouse oocytes by region and countries

Region/ Country	Batches			Oocytes			Transferrable embryos		
	Dairy	Beef	Total	Dairy	Beef	Total	Dairy	Beef	Total
Europe									
Greece	**8**	**0**	**8**	**0**	**0**	**0**	**30**	**0**	**30**
Italy	**0**	**5**	**5**	**0**	**168**	**168**	**0**	**28**	**28**
Netherlands	**84**	**0**	**84**	**2,350**	**0**	**2,350**	**705**	**0**	**705**
Poland	**86**	**0**	**86**	**695**	**0**	**695**	**166**	**0**	**166**
Portugal	**0**	**1,144**	**1,144**	**0**	**5,088**	**5,088**	**0**	**0**	**0**
Romania	**4**	**0**	**4**	**160**	**0**	**160**	**48**	**0**	**48**
Spain	**8**	**63**	**71**	**51**	**1,178**	**1,229**	**26**	**436**	**462**
N America									
Canada	**12**	**0**	**12**	**183**	**0**	**183**	**76**	**0**	**76**
Mexico	**0**	**10**	**10**	**0**	**2,317**	**2,317**	**0**	**498**	**498**
USA	**0**	**0**	**0**	**999**	**15,900**	**16,899**	**326**	**5,307**	**5,633**
S America									
Argentina	**0**	**2**	**2**	**0**	**99**	**99**	**0**	**17**	**17**
Brazil	**0**	**885**	**885**	**0**	**14,415**	**14,415**	**0**	**3,543**	**3,543**
Peru	**38**	**0**	**38**	**190**	**0**	**190**	**31**	**0**	**31**

Appendix 6: Bovine IVP embryo transfer by region and countries

Region/ Country	Embryos transferred							Exported
	OPU				Abattoir			
	Fresh	Frozen		Total	Fresh	Frozen	Total	
		Domestic	Foreign					
Africa								
Rep South Africa	**1,611**	**337**	**0**	**1,948**	**0**	**0**	**0**	**0**
Centr America								
Dominican Rep	**1,462**	**366**	**0**	**1,828**	**0**	**0**	**0**	**0**
Panama	**5,161**	**0**	**0**	**5,161**	**0**	**0**	**0**	**0**
Europe								
Belgium	**0**	**0**	**1,315**	**1,315**	**0**	**0**	**0**	**0**
Estonia	**17**	**0**	**0**	**17**	**0**	**0**	**0**	**0**
Finland	**19**	**457**	**0**	**476**	**0**	**0**	**0**	**0**
France	**369**	**348**	**54**	**771**	**0**	**0**	**0**	**88**
Germany	**2,007**	**909**	**0**	**2,916**	**0**	**0**	**0**	**0**
Hungary	**0**	**0**	**105**	**105**	**0**	**0**	**0**	**0**
Italy	**126**	**15**	**0**	**141**	**0**	**0**	**0**	**0**
Netherlands	**11,124**	**10,354**	**0**	**21,478**	**0**	**0**	**0**	**0**
Poland	**23**	**17**	**0**	**40**	**0**	**0**	**0**	**0**
Romania	**0**	**1**	**0**	**1**	**12**	**3**	**15**	**0**
Russian Fed,	**8,587**	**6,172**	**0**	**14,759**	**0**	**0**	**0**	**0**
Serbia	**12**	**37**	**0**	**49**	**0**	**0**	**0**	**0**
Spain	**59**	**158**	**0**	**217**	**49**	**282**	**331**	**0**
Switzerland	**0**	**14**	**81**	**95**	**0**	**0**	**0**	**0**
United Kingdom	**0**	**117**	**0**	**117**	**0**	**0**	**0**	**0**
N America								
Canada	**4,713**	**4,110**	**0**	**8,823**	**0**	**0**	**0**	**274**
Mexico	**16,528**	**11,209**	**245**	**27,982**	**96**	**0**	**96**	**0**
USA	**180,081**	**80,112**	**0**	**260,193**	**0**	**0**	**0**	**3,503**
Oceania								
Australia	**10,046**	**680**	**0**	**10,726**	**0**	**0**	**0**	**0**
S America								
Argentina	**16,084**	**12,434**	**0**	**28,518**	**0**	**17**	**17**	**97**
Brazil	**229,301**	**43,968**	**0**	**273,269**	**2,325**	**89**	**2,414**	**0**
Bolivia	**3,476**	**0**	**0**	**3,476**	**0**	**0**	**0**	**0**
Ecuador	**1,830**	**76**	**0**	**1,906**	**0**	**0**	**0**	**0**
Paraguay	**33,727**	**23,102**	**0**	**56,829**	**0**	**0**	**0**	**0**
Peru	**154**	**13**	**0**	**167**	**18**	**15**	**33**	**0**
Uruguay	**6,324**	**1,581**	**0**	**7,905**	**0**	**0**	**0**	**0**
Venezuela	**8,774**	**0**	**0**	**8,774**	**0**	**0**	**0**	**0**