AS 662 ASL R3072

2016

Impact of Embryo Transfer Technology on the Production of Artificial Insemination Sires for the U.S. Dairy Cattle Industry

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A.S. Leaflet R3072

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Summary and Implications

Embryo transfer has played an important role in genetic improvement of dairy cattle over the past several decades. Embryo transfer (ET) has impacted the dairy cattle industry not only through the production of cows via ET, but also through the production of bulls who have subsequently been utilized in the artificial insemination (AI) industry. In this study we attempted to quantify the magnitude of impact that ET has made in the production of AI sires used in the U.S. dairy cattle industry. By analyzing publically available data from five major bovine AI companies we discovered that 99% of currently available Holstein AI sires and 95% of currently available Jersey AI sires were produced via ET or had parents or grandparents produced via ET. These data clearly demonstrate the impact that ET has played in dairy cattle genetic improvement through the production of AI sires. To the best of our knowledge these data are the first to quantify the impact of ET technology on production of AI sires used in U.S. dairy cattle industry.

Introduction

Two of the most important agricultural biotechnologies that have been widely utilized to enhance genetic improvement in the U.S. dairy cattle industry are artificial insemination and embryo transfer. Artificial insemination (AI) allows genetically superior bulls to produce large numbers of progeny in a short time period. Embryo transfer (ET) enables genetically superior cows to likewise produce a large number of progeny in a short period of time through transfer of their embryos into recipient females. The first successful bovine embryo transfer was performed in Wisconsin in 1950 (Willett et al., 1951, Science 113:247).

The U.S. dairy cattle industry is a large multibillion-dollar industry. According to the United States Department of Agriculture (USDA) National Agriculture Statistic Service (NASS), 9.3 million cows were being milked in the U.S on July 1, 2015 (http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1017). Most of these milking cows become pregnant through AI. In 2014 , the National Association of Animal Breeders (NAAB) marketed 23.3 million units of frozen dairy cattle semen (http://www.naab-css.org/sales/table35.html). In addition to AI, however, some dairy cows become pregnant via ET. The American Embryo Transfer Association (AETA) reported that 16,010 embryo recoveries and 12, 802 oocyte recoveries were performed in dairy cows in 2013 (http://www.aeta.org/survey/asp). Oocytes were recovered to produce embryos in the lab utilizing in vitro fertilization (IVF) technologies.

Because of the large difference between the number of units of dairy cattle semen marketed each year and the number of embryo and oocyte recoveries, some people claim that ET hasn't had much of an impact on the U.S. dairy cattle industry because fewer cattle are produced via ET than are produced via AI. However, we hypothesized that ET has had a significant impact on the U.S. dairy cattle industry through its role in the production of offspring subsequently used as AI sires. Therefore, we initiated a study to better quantify the impact of ET on dairy cattle genetic improvement.

Materials and Methods

The volume of ET activity within the U.S. dairy cattle industry has been reasonably well documented by the American Embryo Transfer Association (AETA). However, these AETA data do not fully document the magnitude of impact that ET has made on the dairy cattle industry. To study one avenue through which ET has impacted the US dairy cattle industry – the production of AI sires - we collected publically available data from five bovine AI companies with a strong presence in the United States (ABS Global, Accelerated Genetics, Alta Genetics, GENEX Cooperative, and Select Sires). Each company's dairy sire listings were analyzed by breed (e.g., Holstein, Jersey, Ayrshire). Because the Holstein and Jersey breeds make up 95% of the total number of AI sires for which semen is marketed in the U.S., we limited the major portion of our investigation to these two breeds. An excel spread sheet was created for each breed that included:

- name of each AI sire
- whether or not the AI sire was produced via ET
- whether or not the AI sire's parents (dam and/or sire) were produced via ET
- whether or not the AI sire's grandparents (maternal grandsire {MGS} and/or maternal granddam {MGD}) were produced via ET

Table 1 provides a partial illustration of the spreadsheet created for each breed within an individual bovine AI company. This table includes specifically chosen examples of bulls with varying influences of ET in their pedigrees.

Table 1. Example of spreadsheet created for Jersey AI sires marketed through one of the five major bovine AI companies (i.e., Accelerated Genetics).

AI sire name	AI sire produced via ET?	Parents of AI sire produced via ET?	Grandparents of AI sire produced via ET? *
Revolution	Yes	No	No
Avon	Yes	Yes (Sire)	Yes (MGS)
Jumbo	Yes	Yes (Dam & Sire)	Yes (MGS)
Method	No	Yes (Dam & Sire)	Yes (MGS)
Bonanza	No	No	Yes (MGS)
Lemonhead	No	Yes (Dam)	Yes (MGS)

*MGS denotes maternal grandsire

Once each AI sire's information was recorded in the spreadsheet for each company, spreadsheets for all five companies were merged. The merged spreadsheet was edited so that any AI sire marketed by more than one company was listed only once.

In the final spreadsheet, data were analyzed within company to determine the total number of sires that were produced via ET, whether or not the AI sire's parents were produced via ET, and whether or not the AI sire's grandparents were produced via ET. Percentages of animals within each category across breeds and companies were then computed and recorded. A chi-square analysis was performed to determine breed differences in prevalence of ET heritage in the AI sires.

After completion of the data analysis, info-graphics were developed using the online publication program PiktoChart. One info-graphic was created for each breed (Holstein and Jersey) to illustrate the percentage of animals whom had ET represented in their pedigree.

Results and Discussion

Results of the analysis are presented in Table 2 for Holstein AI sires and in Table 3 for Jersey AI sires. More ($P < 0.001$) Holstein than Jersey AI sires were themselves produced via ET (81.4% vs. 54.4%, respectively). There was a greater ($P<0.001$) proportion of Holstein than Jersey AI sires who had one or more parents produced via ET (91.1% vs. 73.6%, respectively). A similar breed difference was observed ($P<0.001$) in the proportion of AI sires who had one or more grandparents produced via ET (92.3% for Holstein vs. 61.9% for Jersey).

Complete data were available to permit analysis of Holstein (Table 4) and Jersey (Table 5) AI sires whose parents had been produced via ET. A greater ($P<0.001$) proportion of Holstein AI sires were derived from sires & dams who themselves were produced via ET (51%) than Jersey sires (27%). There were more ($P<0.001$) Jersey AI sires with neither parent being produced via ET (23%) compared with Holsteins (9%).

Figure 1 visually depicts the results of this study for the 2015 Holstein AI sires, and Figure 2 illustrates results for the 2015 Jersey AI sires.

In dairy cattle genetic improvement there are four distinct pathways through which genetic change can be achieved (Robertson and Rendel, 1950, J. Genet. 50:21). These four pathways are: 1) bulls used to produce future bulls, 2) cows used to produce future bulls, 3) bulls used to produce future cows, and 4) cows used to produce future cows. Approximately 40% of genetic improvement is due to pathway 1, 33% to pathway 2, 23% to pathway 3, and 4% to pathway 4 (Cassell, 1988, J Dairy Sci 71:1993 – 2000).

Although embryo transfer can theoretically contribute to genetic improvement through all four of the above pathways, for our study we focused on pathway 2 (cows to produce future bulls). We felt that this genetic improvement pathway is frequently overlooked when people consider the impact of ET on the U.S. dairy cattle industry. Data gathered by AETA are not segregated based on the producers' intended use of the ET offspring; however, our understanding of the ET industry suggests that genetic improvement pathway 4 (cows to produce future cows) is the most commonly perceived reason that ET is performed in the U.S. dairy cattle industry.

The data from AETA indicates that approximately 0.31% of the nation's 9.3 million dairy cows undergoes embryo or oocyte recovery. This relatively low percentage is the reason why some people erroneously conclude that ET has played a minor role in dairy cattle genetic improvement. However, such persons often do not fully consider that the most rapid genetic change can be accomplished by being extremely high selective in choosing parents of the next generation of offspring. Thus, it is quite appropriate that only a small number of dairy cows is utilized for embryo production and subsequent transfer.

We believe this study is the first attempt to document the significant role ET has played in the production of AI sires and hence in U.S. dairy cattle genetic improvement.

Acknowledgements

Special thanks are given to Darin Peterson and Martha Amidon from Alta Genetics for permission to use their images of 'AltaIota' and 'Viceroy'. We also greatly acknowledge PiktoChart for use of their program to generate info-graphics. Sincere appreciation is extended to Dr. Diane Moody-Spurlock and Dr. Leo Timms for their highly useful suggestions to improve this article.

Table 2. Role of embryo transfer (ET) in production of commercially available Holstein artificial insemination (AI) sires

Artificial insemination (AI) company	Number of AI sires available	Number (%) of AI sires produced via ET	Number (%) of AI sire's parents produced via ET	Number (%) of AI sire's grandparents produced via ET	AI sires with no ET in 3-generation pedigree
ABS Global	163	146 (90%)	149 (91%)	151 (93%)	0 (0%)
Accelerated Genetics	142	118 (83%)	136 (96%)	136 (96%)	3 (2.1%)
Alta Genetics	335	240 (71%)	274 (82%)	298 (89%)	3 (0.9%)
GENEX Cooperative	147	119 (81%)	142 (97%)	133 (91%)	0(0%)
Select Sires	211	189 (90%)	205 (97%)	203 (96%)	0(0%)
TOTALS	998	812 (81%)	906 (91%%)	921 (92%)	6 (0.6%)

Table 3. Role of embryo transfer (ET) in production of commercially available Jersey artificial insemination (AI) sires

Artificial insemination (AI) company	Number of AI sires available	Number (%) of AI sires produced via ET	Number (%) of AI sire's parents produced via ET	Number (%) of AI sire's grandparents produced via ET	AI sires with no ET in 3-generation pedigree
ABS Global	40	24 (60%)	35 (88%)	29 (73%)	1 (2.5%)
Accelerated Genetics	74	40 (54%)	50 (68%%)	45 (61%)	3 (4.0%)
Alta Genetics	49	25 (51%)	35 (71%)	22 (45%)	2 (4.1%)
GENEX Cooperative	45	23 (51%)	36 (80%)	29 (64%)	1 (2.2%)
Select Sires	34	22 (64%)	30 (88%)	26 (77%)	3 (8.8%)
TOTALS	242	134 (55%)	186 (77%)	151 (62%)	12 (5.0%)

Table 4. Influence of embryo transfer (ET) in production of parents of commercially available Holstein artificial insemination (AI) sires

Artificial insemination (AI) company	Number of AI sires available	Holstein AI sire whose parent(s) was produced via ET			
		Male parent only	Female parent only	Both male and female parent	Neither parent
ABS Global	163	34 (21%)	24 (15%)	91 (56%)	14 (9%)
Accelerated Genetics	142	38 (27%)	25 (18%)	73 (51%)	6 (4%)
Alta Genetics	335	69 (21%)	87 (26%)	118 (35%)	61 (18%)
GENEX Cooperative	147	34 (23%)	19 (13%)	89 (61%)	5 (3%)
Select Sires	211	29 (14%)	37 (18%)	139 (66%)	6 (3%)
Totals	998	204 (20%)	192 (19%)	510 (51%)	92 (9%)

Table 5. Influence of embryo transfer (ET) in production of parents of commercially available Jersey artificial insemination (AI) sires

Artificial insemination (AI) company	Number of AI sires available	Jersey AI sire whose parent(s) was produced via ET			
		Male parent only	Female parent only	Both male and female parent	Neither parent
ABS Global	40	9 (23%)	13 (33%)	13 (33%)	5 (13%)
Accelerated Genetics	74	26 (35%)	7 (9%)	17 (23%)	24 (32%)
Alta Genetics	49	17 (35%)	5 (10%)	13 (27%)	14 (29%)
GENEX Cooperative	45	20 (44%)	5 (11%)	11 (24%)	9 (20%)
Select Sires	34	14 (41%)	5 (15%)	11 (32%)	4 (12%)
Totals	242	86 (36%)	35 (14%)	65 (27%)	56 (23%)

Figure 1. Role of embryo transfer (ET) in production of commercially available Holstein artificial insemination (AI) sires

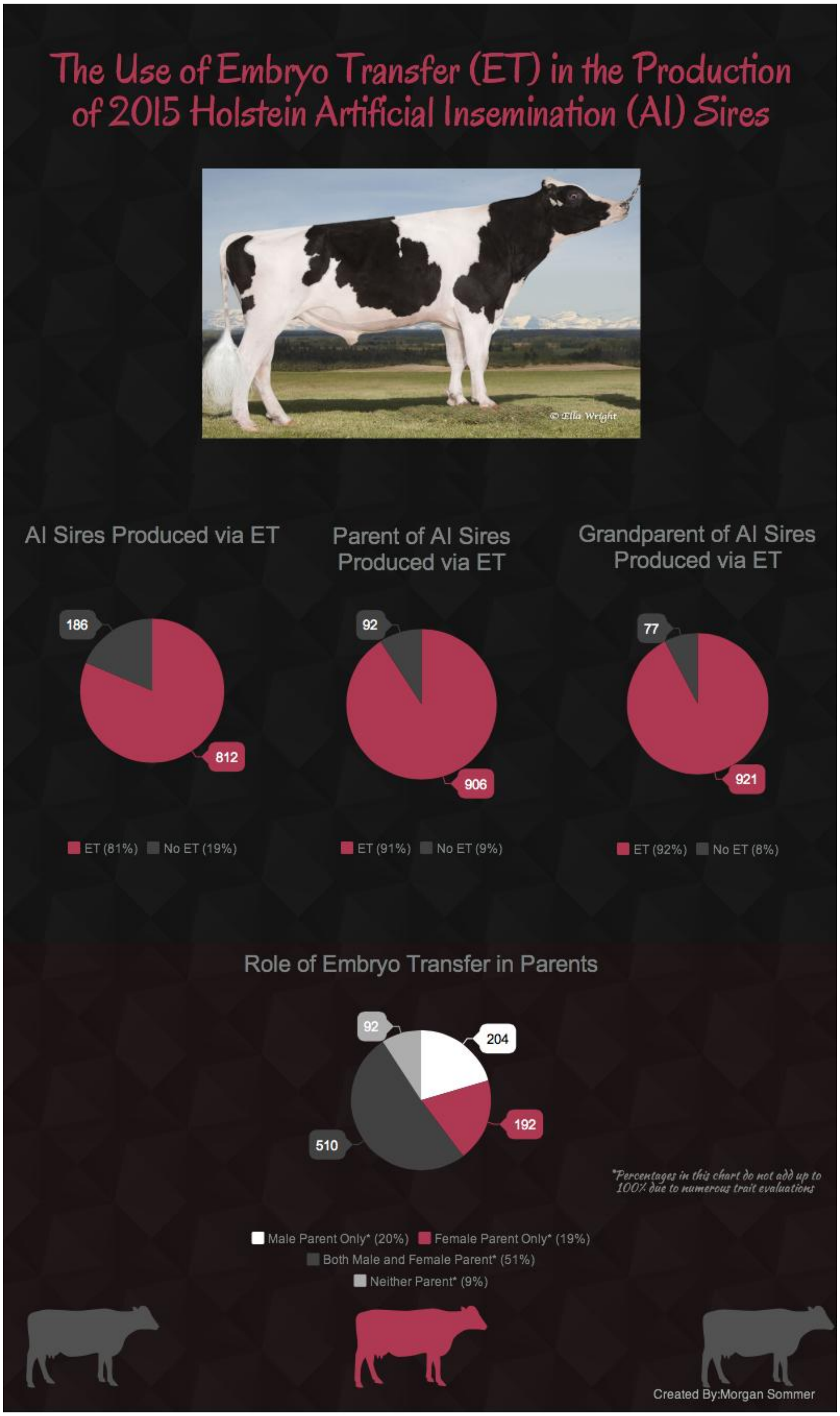

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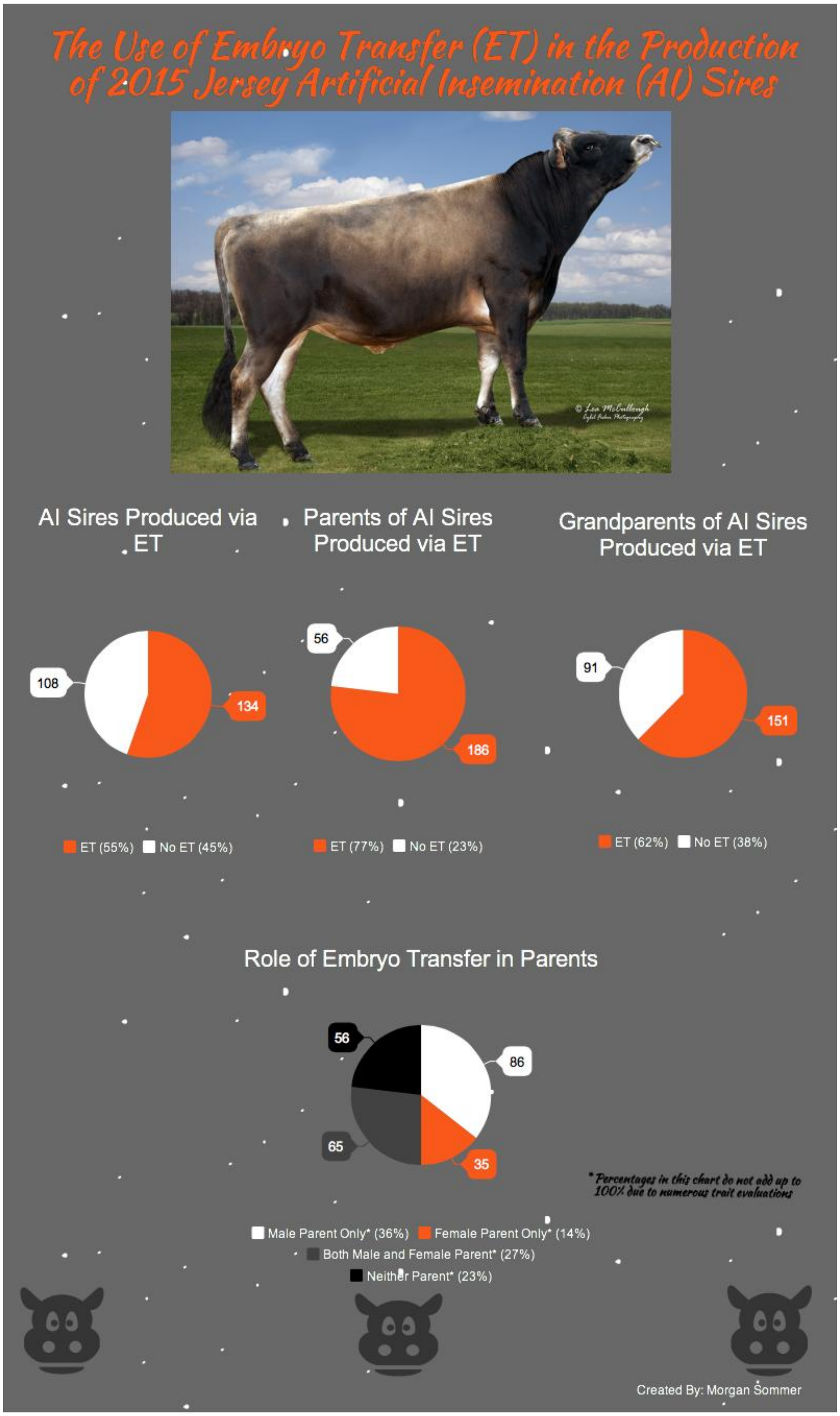
Figure 2. Role of embryo transfer ET) in production of commercially available Jersey artificial insemination (AI) sires



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