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CASE STUDY: Retention and readability of radio frequency identification transponders in beef cows over a 5-year period[1]

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ABSTRACT

The objective of this study was to evaluate failure (loss or inability to read) of radio frequency identification (RFID) ear tags in beef cows over a 2- to 5-yr period under ranch conditions. One of 5 types of RFID tags (Allflex HDX, Allflex FDX, Y-Tex FDX, Z-Tag FDX, and Destron FDX) was applied in the ear of a total of 4,316 cows on 4 separate locations (ranches). Tags were evaluated at approximately yearly intervals for either 2 (ranch 1), 3 (ranch 2 and 3), or 5 yr. Percentages of tags that were lost or that failed to read were 1.4, 1.6, 3.7, 5.1, and 5.0 for the 5 consecutive annual evaluations, respectively, when averaged across ranches and RFID tag type. Cumulative losses of 3.0, 6.0, and 19.8% were observed when averaged over all tag types after 2 (all 4 ranches), 3 (3 ranches), and 5 yr (1 ranch). A ranch by tag type interaction was evident for failure of the 2 types of tags evaluated on all 4 ranches; a greater proportion of Allflex HDX tags were lost than Allflex FDX tags at ranch 4 (36 vs. 4%) but not at other ranches (4.7 vs. 5.1% cumulative loss–fail rate for HDX and FDX). This interaction may be due to differences in tag placement. Tags were placed in the top of the ear at ranch 4 but were attached between the second and third ribs of the ear at ranch 1, 2, and 3. Results indicate that loss of RFID tags increases with time after application and may exceed 5% after 3 yr.

Key words: cattle, retention, RFID tag

INTRODUCTION

A major issue in animal agriculture in the past decade has been attempts to develop a national animal identification program to facilitate monitoring of animal movement and provide 48-h trace back in case of a disease outbreak. For several species, including beef cattle, radio frequency identification (**RFID**) ear tags have been proposed as a method for identifying and tracking individual animals. This technology provides many characteristics that make it well suited for the intended purpose, including capacity for individual identification, collection of data on a real-time basis, and ease of data entry into databases allowing sorting and rapid traceability. Several companies manufacture RFID tags with standardized specifications providing multiple sources for the tags and the scanners used to read them. Information concerning performance of different RFID tags and scanners with regard to distances and rates of scanning has been published (Wallace et al., 2008; Ryan et al., 2010). However, for any identification system to work, it must function over the life of the animals involved. Previous studies have shown that retention of RFID tags from weaning to slaughter was 97 to 100% (Kellom et al., 2006). Data concerning long-term evaluation of retention and readability of tags in cows under production environments are lacking. The objective of the present study was to provide insight into retention and readability of RFID tags in cows under ranching environments over a 2- to 5-yr period.

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana AES, or the authors and does not imply its approval to the exclusion of other products that may also be suitable. USDA, ARS, Northern Plains Area, is an equal opportunity/affirmative action employer. All agency services are available without discrimination.

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MATERIALS AND METHODS

One of 5 types of RFID ear tags was applied in the ear of a total of 4,316 cows at 4 separate locations in Montana. For 3 locations [2 commercial ranches (ranch 1 and 2) and the USDA, ARS, Ft. Keogh Livestock and Range Research Laboratory], tags were applied from late August through December of 2005. In the remaining location (ranch 3), tags were applied in September or November of 2006. The 5 types of tags applied were the Allflex Full Duplex Technology (**Allflex FDX**) Lightweight Ultra Bovine EID tag (Allflex USA Inc., DFW Airport, TX); Allflex Half Duplex Technology High Performance Ultra EID tag (**Allflex HDX**); **Destron** Fearing FDX E.Tag (Digital Angel Corp., South St. Paul, MN); **Y-Tex** FDX RFID tag (Y-Tex Corp., Cody, WY); or **Z-Tag** FDX RFID tag (Farnam Co. Inc., Phoenix, AZ). All tags were scanned before application to cows to ensure they were functioning properly at the start of the study. The number of each type of tag applied at each location is summarized in Table 1. Tags were applied between the second and third ribs of the ear at ranch 1, 2, and 3. Tags were applied in the top of the ear at Ft. Keogh (ranch 4; Figure 1) because visual identification tags had already been applied between the second and third ribs of each ear.

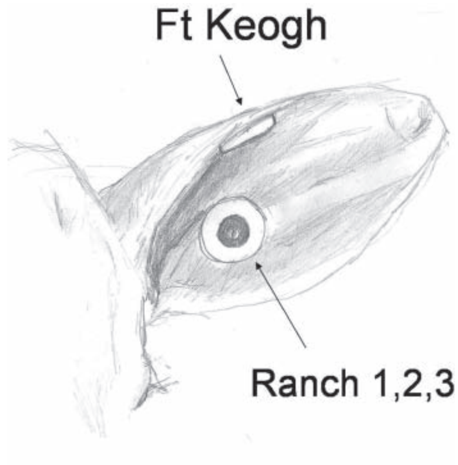

Figure 1. Locations of radio frequency identification (RFID) tags.

Readability and retention of tags was evaluated at approximately annual intervals when cows were processed through working chutes each fall. As indicated in Table 1, Allflex FDX and Allflex HDX tags were evaluated at all locations; in addition, Y-Tex and Z-Tag tags were evaluated at ranch 1 and 3, and Destron tags were evaluated at ranch 2 and 3. Tags that were lost or failed to scan during annual evaluations were replaced before subsequent evaluations or the cow was removed from the study. For tags that were replaced, date of new tag application was used as the starting point to calculate duration of retention and function of the new tag. Replacement tags were applied in the original location (i.e., same hole) when possible.

Differences in failure times (loss or failure to read) among types of tags and ranches (nominal variables) were analyzed by the LIFEREG procedure of SAS (SAS Institute Inc., Cary, NC). Data from tags that had not failed (remained in place and were readable) by the end of the evaluation period for each ranch were considered to be right censored. Because it was not possible to evaluate all tag types at all ranches, different analyses were run to allow comparison of tag types

Table 1. Number of cows observed each year and number radio frequency identification (RFID) tags lost or that failed to read

		Yr 1			Yr 2			Yr 3			Yr 4[2]		Yr 5[2]	
Ranch	Tag[1]	n	Lost	Fail to read	n	Lost	Fail to read	n	Lost	Fail to read	n	Lost	n	Lost
Ft. Keogh	FDX	201	0	0	197	0	0	169	3	0	149	2	136	2
Ft. Keogh	HDX	205	0	0	201	20	0	162	31	0	125	12	105	10
1	FDX	201	1	1	199	2	2	195	4	2				
1	HDX	235	3	0	232	2	0	230	11	0				
1	Y-Tex	226	12	0	214	6	0	208	3	0				
1	Z-Tag	192	4	0	188	3	1	184	11	1				
2	Destron	568	3	0	565	2	0	481	4	1				
2	FDX	563	3	3	555	4	8	463	1	8				
2	HDX	783	2	1	760	8	0	649	21	0				
3	Destron	229	3	0	226	0	0							
3	FDX	231	3	0	228	1	0							
3	HDX	234	0	0	234	0	0							
3	Y-Tex	225	17	0	208	5	2							
3	Z-Tag	223	2	3	218	1	1							

[1]FDX = Allflex Full Duplex Lightweight Ultra Bovine EID tag (Allflex USA Inc., DFW Airport, TX); HDX = Allflex Half Duplex High Performance Ultra EID tag (Allflex USA Inc.); Y-Tex = Y-Tex Full Duplex RFID tag (Y-Tex Corp., Cody, WY); Z-Tag = Z-Tag Full Duplex RFID tag (Farnam Co. Inc., Phoenix, AZ); Destron = Destron Fearing Full Duplex E.Tag (Digital Angel Corp., South St. Paul, MN).

[2]All tags read when scanned.

that were common across ranches. Initial models included brand of tag, ranch, and the brand of tag by ranch interaction. When the brand of tag by ranch interaction was significant ($P < 0.05$), data were recoded with a separate coding for each tag by ranch classification. Data were then reanalyzed using a model that included recoded classification, and estimates of the 95% confidence limits were used to determine differences between tag classifications.

Although failure of a tag to read may be considered a failure in performance, it would still be possible to visually read numbers printed on the RFID tags and thus identify the animal. Therefore, all analyses described above were repeated after removing tags that failed to scan from the data to differentiate between the 2 possible causes of failure.

When the LIFEREG procedure indicated differences in failure time, chi-squared analyses were performed on proportions of tags lost or failing to read at each evaluation time to provide insight into when differences began to be observed. Differences in failure rate between Allflex FDX and Allflex HDX tags among the different ranches were evaluated on all data available for each evaluation time point. Data from ranch 1 and 3 were used to compare performance of Y-Tex and Z-Tag tags with Allflex FDX and Allflex HDX tags, for first and second yearly intervals and cumulative loss over 2 yr. Failure rates of these tags during the third year were compared within ranch 1. Data from ranch 2 and 3 were used to compare Destron tags to Allflex FDX and Allflex HDX tags. Failure rates of these tags during the third year were compared within ranch 2.

RESULTS AND DISCUSSION

Numbers of each type of RFID tags that were lost or failed to read at the annual evaluation at each ranch are reported in Table 1. Percentage of tags that failed because of loss or inability to be read were 1.4, 1.6, 3.7, 5.1, and 5.0% for the 5 consecutive annual evaluations, respectively, when summarized across ranches and RFID tag types represented at each time point. Cumulative loss and read failure across ranches and RFID tag types represented at each time point were 3.0, 6.0, 16.7, and 19.8% for 2, 3, 4, and 5 yr after tag application.

Analysis of time to failure (lost or failed to read) for Allflex FDX and Allflex HDX tags applied on all ranches indicated that time to failure for these 2 types of tags differed among ranches ($P < 0.001$ for tag type by ranch interaction). To provide insight into this interaction, data were reanalyzed after reclassification into the 4 groupings shown in Table 2. Estimates of time to failure from this analysis were earliest for Allflex HDX tags in cows at Ft. Keogh and latest for Allflex FDX tags in cows at Ft. Keogh, with intermediate times for either tag type in cows at the 3 commercial ranches. Similar results were obtained when data for failure to read were removed from the analysis, indicating tag loss as the predominant factor contributing to failure. To provide greater insight into the ranch by tag type interaction, chi-squared comparisons of tag loss and read failure were performed on data from each yearly evaluation (Table 2). At 1 yr after application, combined loss and read failure was greater ($P < 0.001$) in cows at the 3 commercial ranches (range of 0.5 to 1.1% over ranches) than at Ft. Keogh (0%). When evaluated within the 3 commercial ranches, there was a tendency ($P = 0.10$) for a greater proportion of Allflex FDX tags failing to scan (0.5%) than Allflex HDX tags (0.1%) at 1 yr after application (Table 2). The difference in rate of read failure became even greater ($P < 0.01$) at the second (1.0 vs. 0% for Allflex FDX vs. Allflex HDX) and third year (1.5 vs. 0%, respectively) after tagging for these 3 ranches but not at Ft. Keogh (Table 2). Loss of tags during the second year after tagging was greater ($P < 0.01$) for Allflex HDX tags at Ft. Keogh (10%) than for Allflex FDX tags at Ft. Keogh (0%) or either tag type in cows located on the 3 commercial ranches. Tag loss during at the third year after application continued to be greater ($P < 0.001$) for Allflex HDX tags in cows at Ft. Keogh (19.1%) than for other tag by ranch classifications, and a greater percentage of Allflex HDX tags (3.6%) were lost than Allflex FDX tags (0.8%) when compared across the 3 commercial ranches ($P < 0.001$). Cumulative loss and read failure of Allflex HDX in cows at Ft. Keogh after 2 (9.8%) or 3 yr (24.9%) was greater than loss and failure of Allflex HDX averaged over the other 3 ranches (1.3 and 4.7% for 2- and 3-yr cumulative loss) or Allflex FDX loss–read failure rate averaged over all 4 ranches (2.3 and 4.3% for 2- and 3-yr cumulative loss–read fail rate). In cows evaluated at Ft. Keogh, loss during the fourth and fifth year after application continued to be greater ($P < 0.01$) for Allflex HDX tags than for Allflex FDX tags (9.6 vs.1.3% and 9.5 vs. 1.5% for Allflex HDX vs. Allflex FDX at yr 4 and 5, respectively). Cumulative losses after 4 and 5 yr were 2.5 and 3.5% for Allflex FDX tags and 30.7 and 35.6% for Allflex HDX tags applied to cows at Ft. Keogh.

Although the study was not specifically designed to test differences in site of tag application, it is expected that the differences in tag placement contributed to the ranch by tag type interaction described above. Visual appraisal of tags during processing of cows revealed that the stud holding tags in place was deteriorated, resulting in separation of the shank and back of the stud, which would allow tags to slip out of the ear. It is speculated that placement of tags in a more vertical alignment, as done in Ft. Keogh cows, may result in greater stress on the stud than when tags are applied in a horizontal alignment, as done at the commercial ranches. The heavier weight of the Allflex HDX tags (8.9 g) would be expected to result in greater fatigue of the stud compared with the lighter Allflex FDX tags (5.6 g), which might contribute to greater loss of Allflex HDX tags, especially when applied in a vertical position. However, since comple-

Table 2. Percentage of Allflex FDX and HDX tags lost or that failed to read over time[1]

Ranch	Allflex tag[2]	Yr 1 Lost	Yr 1 Fail to read	Yr 2 Lost	Yr 2 Fail to read	Yr 3 Lost	Yr 3 Fail to read	2-yr cumulative loss and fail	3-yr cumulative loss and fail
Ft. Keogh	FDX	0.0	0.0	0.0	0.0	1.8	0.0	0.0	1.8
Ft. Keogh	HDX	0.0	0.0	10.0*	0.0	19.1*	0.0	9.8*	24.9*
1, 2, 3	FDX	0.6	0.5	0.7	1.0*	0.8	1.5*	2.8	5.1
1, 2, 3	HDX	0.4	0.1	0.8	0.0	3.6†	0.0	1.3†	4.7

[1]$P < 0.001$ for interaction of ranch group and tag type.

[2]FDX = Allflex Full Duplex Lightweight Ultra Bovine EID tag (Allflex USA Inc., DFW Airport, TX); HDX = Allflex Half Duplex High Performance Ultra EID tag (Allflex USA Inc.).

*Differs from other values in the same column ($P < 0.05$).

†Differs from FDX ($P < 0.01$) when compared within ranch group.

tion of the present study, Allflex no longer markets the Lightweight Ultra Bovine FDX tag evaluated in this study. The Lightweight Ultra Bovine FDX tag has been replaced with a thicker, heavier FDX tag that may improve function (decrease read failure rate) but increase loss rate above that observed for Allflex FDX tags evaluated in the present study. Further research is required to confirm the influence of tag weight on loss rate.

Analysis of time to failure for Y-Tex, Z-Tag, Allflex HDX, and Allflex FDX tags applied to cows at ranch 1 and 3 indicated differences among tag types ($P < 0.001$), with failure time being earlier for Y-Tex tags than for either Allflex HDX or FDX tags. Estimated failure time for Z-Tags was intermediate and not different from other tag types. Similar results were obtained from analysis of time to failure after removing tags that failed to read from the data, except that time to failure was earlier ($P < 0.05$) in Y-Tex than in Z-tag tags. Comparison of the different types of RFID tags at each of the yearly evaluations (Table 3) revealed a greater proportion of Y-Tex tags were lost (6.4%) within the first year after application compared with the other 3 types of tags. Read failure rates at 1 yr after application tended ($P < 0.09$) to be greater for Z-Tags than for Allflex FDX tags (Table 3), with no Allflex HDX or Y-Tex tags failing to read. When loss and read failure rates were combined, a greater proportion of Y-Tex tags failed (6.4%) within the first year after application compared with the other 3 types of tags (0.6, 1.2, and 2.2% for Allflex HDX, Allflex FDX, and Z-Tag, respectively). Loss of Y-Tex tags between the first and second year (2.6%) after application exceeded ($P < 0.03$) that of Allflex HDX (0.4%) and Allflex FDX (0.7%) and tended ($P = 0.08$) to be greater than that of Z-Tag tags (1.0%). Incidence of tags that failed to read did not vary by type of tag at 2 yr after application. When loss and read failures were combined, proportion of Y-Tex tags failing (3.1%) exceeded that of Allflex HDX tags (0.4%; $P = 0.002$) and Allflex FDX (1.2%; $P = 0.053$), and proportion of Z-Tags failing (1.5%) was intermediate but not different from other tag types. Cumulative loss and read failure over both years was greater for Y-Tex tags (9.3%) than for other tags. Cumulative loss of Z-Tags (3.6%) did not differ from that observed for Allflex FDX (2.3%) but was greater than loss of Allflex HDX tags (1.1%). At the third year after application (data only available for ranch 1), a greater proportion of Z-Tags (6.5%) were lost than Y-Tex (1.4%) or FDX (2.1%) tags. Loss of Allflex HDX (4.8%) was greater ($P = 0.05$) than that of Y-Tex but was not different from the other 2 types of tags. Cumulative loss and read failure after 3 yr was similar ($P = 0.30$) among the 4 tag types.

Analysis of time to failure for Destron, Allflex HDX, and Allflex FDX tags applied to cows at ranches 2 and 3 indicated differences among tag types ($P = 0.026$), with Allflex FDX having earlier time of failure compared with Destron tags. Time of failure for Allflex HDX was not different from the other tag types. No differences ($P = 0.19$) in time to failure were observed between tag types when data for failure to read were removed from the analysis, indicating that read failure was contributing to the earlier time of failure observed for FDX tags. Proportions of tags lost at 1 and 2 yr after application were not different for the 3 tag types (Table 4). Rate of read failure at 1 and 2 yr after applications was less ($P < 0.05$) for Destron tags than for Allflex FDX tags. Combined loss and read failure during the second year after tag application was less ($P < 0.01$) for Destron (0.3%) than for Allflex FDX tags (1.7%), with Allflex HDX tags being intermediate (0.8%). Combined loss and read failure rate accumulated over 2 yr after application was less ($P < 0.05$) for Destron (1.0%) and HDX (1.1%) tags than for FDX tags (2.8%). Loss of tags during the third year after application (data from ranch 2 only) was less ($P < 0.05$) for Destron (0.8%) and Allflex FDX

Table 3. Average percentage of Allflex FDX, Allflex HDX, Y-Tex, and Z-Tag radio frequency identification (RFID) tags lost or that failed to read at different times after tagging on ranches 1 and 3

	Yr 1		Yr 2		Yr 3[2]			
Tag[1]	Lost	Fail to read	Lost	Fail to read	Lost	Fail to read	2-yr cumulative loss and fail	3-yr cumulative loss and fail[2]
FDX	0.9	0.2[ab]	0.7[a]	0.5	2.1[ab]	1.0	2.3[bc]	6.0
HDX	0.6	0.0[a]	0.4[a]	0.0	4.7[bc]	0.0	1.1[c]	6.8
Y-Tex	6.4[a]	0.0[a]	2.6[b]	0.5	1.4[a]	0.0	9.3[a]	9.3
Z-Tag	1.0	1.2[b]	1.0[a]	0.5	6.5[c]	0.0	3.6[b]	10.4

[a–c]Numbers within a column without a common superscript differ (*P* < 0.05).

[1]FDX = Allflex Full Duplex Lightweight Ultra Bovine EID tag (Allflex USA Inc., DFW Airport, TX); HDX = Allflex Half Duplex High Performance Ultra EID tag (Allflex USA Inc.); Y-Tex = Y-Tex Full Duplex RFID tag (Y-Tex Corp., Cody, WY); Z-Tag = Z-Tag Full Duplex RFID tag (Farnam Co. Inc., Phoenix, AZ).

[2]Data for ranch 1 only.

(0.2%) tags than for Allflex HDX tags (3.2%). However, read failure during this time was greater ($P < 0.02$) for Allflex FDX (1.7%) than for either Destron (0.2%) or Allflex HDX (0.0%) tags. Combined loss and read failure during the third year after application was less ($P = 0.015$) for Destron (1.0%) than for Allflex HDX tags (3.2%), with Allflex FDX tags (1.9%) not differing from the other tags. Cumulative loss over 3 yr (data from ranch 2 only) was less ($P < 0.01$) for Destron (1.8%) than for either Allflex HDX (4.1%) or Allflex FDX (4.8%) tags.

Variations in rate of loss and read failure among tag types were evident at the first year after tag application and after 2 or 3 yr from application. When considering the efficacy of RFID ear-tag technology as a method for national animal identification, the first and most critical requirement is that tags remain attached to the animals to provide a permanent method of identification. Without secondary methods of identification, loss of the RFID tag would result in the inability to trace an animal's movements if needed. In the present study, tag loss the first year after application was less than 1% for all but one type of tag. However, as tags got older, a greater incidence of tag loss was observed between each evaluation, with a range of 0 to 10% loss between yr 1 and 2 after application and 0.14 to 19% loss, respectively, between yr 2 and 3. When replacing lost tags, it did not appear that tags had been torn from the ears, which would be indicative that the tags got caught on something and were torn out of the ear. Based on visual appraisal of tags remaining in cows, it appears that the studs that hold the tags in the ear were deteriorating over time, allowing the tags to fall out of the ear. Changes in materials used for the tags or design may help overcome this limitation.

Failure of RFID tags to read is less problematic for the efficacy of this technology than tag loss. As long as an animal can be restrained and the printed number on the RFID be determined by visual observation, history of the animal's movements could still be determined. However, problems with tags not reading could be disruptive to the normal speed of commerce. A visual appraisal of tag loss and read failure data over time indicates that rate of read failure was less affected by time elapsed after

Table 4. Percentage of Destron, Allflex FDX, and Allflex HDX tags lost or that failed to read at different times after tagging on ranches 2 and 3

	Yr 1		Yr 2		Yr 3[2]			
Tag[1]	Lost	Fail to read	Lost	Fail to read	Lost	Fail to read	2-yr cumulative loss and fail	3-year cumulative loss and fail[2]
Destron	0.8	0.0[a]	0.3	0.0	0.8	0.2	1.0	1.8[a]
FDX	0.6	0.5[b]	0.6	1.0[a]	0.2	1.7[a]	2.8[a]	4.8
HDX	0.2	0.1[ab]	0.8	0.0	3.2[a]	0.0	1.1	4.1

[a,b]Numbers within a column without a common superscript differ (*P* < 0.05).

[1]Destron = Destron Fearing Full Duplex E.Tag (Digital Angel Corp., South St. Paul, MN); FDX = Allflex Full Duplex Lightweight Ultra Bovine EID tag (Allflex USA Inc., DFW Airport, TX); HDX = Allflex Half Duplex High Performance Ultra EID tag (Allflex USA Inc.).

[2]Data for ranch 2 only.

tagging than tag loss. Collectively, these results indicate tag loss will have a much greater negative effect on efficacy of RFID tags as a method of national animal identification than will read failure.

Data generated in this study are from cows that received the RFID tags when they were 1.5 yr of age (replacement heifers) or older. Thus, information generated is applicable to the tagging of all adult animals that would occur at initiation of a national animal identification program. However, all animals born after inception of the program would most likely be tagged at birth or weaning, before transport off the ranch. It is not known whether tag retention data generated in the present study will be indicative of the retention of tags applied at younger ages. With these caveats in mind, it would appear that RFID tags offer an efficient method to monitor movement of calves from the ranch though slaughter, but increases in tag losses over time decrease the efficacy of this technology as a method of life-long identification of animals in the production segment of the industry.

IMPLICATIONS

Results from the present study provide evidence that losses and failure of RFID tags to read over long periods of time may diminish the functionality of this methodology for identifying individual animals as part of a national animal identification, trace back program. In addition, results from the present study indicate the need for considering the effect of retagging on structure of the database, where the RFID tag number would presumably be used as the primary identifier.

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