Field Study on milk production and mastitis effect of the DeLaval Swinging Cow Brush

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Ynte H. Schukken[1] and G. Douglas Young[2]

[1] Quality Milk Production Services, Cornell University, Ithaca, NY 14850.
[2] Sprucehaven Farm and Research Center, Scipio Springs, NY 13160.

Summary

A field study was performed at Sprucehaven Farm and Research Center in New York State, USA. A total of four pens with approximately 100 cows each were used in the study. There were two identical pens of approximately 100 first lactation cows, one with two DeLaval Swinging Cowbrushes (‘Cowbrush’) and one Control pen. The second set of two identical pens housed approximately 100 cows each in second or higher lactation with one pen containing two Cowbrushes and one Control pen. Daily milk production data were available for a period of approximately 3 months before the go-live date of the Cowbrushes and six months after the go-live date. Mixed model linear regression analyses were performed on the daily milk production data. The results indicated that second lactation cows showed an approximate 3.5% (1 kg) higher daily milk production while no statistically significant difference (at $P<.05$) was observed in first lactation or older lactation animals. Clinical mastitis data were collected before and during the field study period. Clinical mastitis was not different between the study pens before the go-live data of the Cowbrushes, however after go-live, clinical mastitis was reduced by 34% ($P<.05$) in the cows in second and higher lactation in the Cowbrush pen. No difference in clinical mastitis was observed in the two pens with first lactation animals.
In conclusion, installation of the Cowbrushes resulted in either no difference in daily milk production (in lactation 1 and 3 and higher), or in an approximate 3.5% (1 kg) higher daily milk production. Clinical mastitis was lower in pens of cows in second and higher lactation with a Cowbrush present.

Introduction

The DeLaval swinging cow brush provides grooming opportunities for dairy cows. Dairy cows have a high need for grooming as was shown recently in a study using a similar cow brush system (DeVries et al., 2007). Cows in a pen with a mechanical brush increased their grooming time approximately 5-fold compared to a pen without such a brush. The authors concluded that a grooming device helps to satisfy the cow’s need for grooming while at the same time improving cow cleanliness. Both these factors (better ‘welfare’ and cleaner cows) may have an impact on disease occurrence and on milk production. Studies have associated cow cleanliness with mastitis incidence (Schreiner

and Ruegg, 2002), and the increased activity of the cow may lead to less metabolic diseases, better digesting and eventually in higher milk production.
Although the intuitive concept of the swinging cow brush being associated with better productivity and increased health may be straightforward, no hard data exist to quantify this potential relationship. Therefore a comparison study of cows experiencing a cow brush was designed, including a contemporary control and pre-study baseline measurements.
The objective of this pilot study is to compare daily milk production and animal health in pens of cows with and without a swinging cow brush on one New York dairy farm.

Study design

The study took place on Sprucehaven Dairy Farm in New York State. This is a well-managed 1800 cow dairy farm. A total of four pens of approximately 100 cows per pen were enrolled in the study. Two of the pens were randomly chosen to have swinging cow brushes installed. Two brushes per pen were installed. The remaining two pens serve as controls. The brushes went live (started functioning) on May 27, 2008 and were installed in Pen 30 with Pen 31 as control and in Pen 27 with Pen 28 as a control. When new cows (after calving, or leaving another pen) entered into a study pen, a random allocation was used to choose either a pen with or without a Swinging cow brush. Data on daily milk production, somatic cell count, clinical mastitis incidence and metabolic diseases were collected in all four pens. When cows move in or out of pens, the movement of the animals was recorded. No cow hygiene or cleanliness scores were performed during the study.

Daily milk weights were made available from February 15, 2008. Data on daily milk production were collected with the Cowbrushes installed starting May 27th 2008 for a 6 month period and the study formally ended on December 1st, however all data were collected until December 15th, 2008. All data were transferred to QMPS in early January. Data analyses started thereafter with initially data checking and cleanup and thereafter the statistical analysis of the data. Overall approximately 89,000 daily milk weight data points were collected and analyzed. Calving data, pen movement data and disease data were collected in the on-farm computer system (DC305) and were made available on a monthly basis to QMPS. Clinical mastitis cases were sampled and culture results were available through QMPS.

Statistical analysis of the data was done using conventional statistical techniques for daily milk production data and disease incidence data (Grohn et al., 1999; Schukken et al., 2003). Statistical models (Generalized Linear Mixed Models) were developed to allow for repeated observations. In the statistical analysis, the cows' location in the pens with the brushes was compared to the cows in the pens without the brushes. Statistical analysis of the data was done separately for first lactation, second lactation cows and multipara as the shape of the lactation curve is quite different between these three groups. The linear mixed model that was used for analysis of each lactation group was:

Milk(kg) = intercept + DIM + exp(-.1*DIM) + Brushpen + Brushon + Month + Month*Brushon + Re,

Where: Milk(kg) is the daily milk production in kilograms, intercept is the overall mean, DIM is days in milk at the time of milk measurement, exp(-.1*DIM) is a correction factor to model the shape of the lactation curve (From Wilmink 1987), Brushpen is an indicator variable for pen with (=1) or without (=0) a Cowbrush, Brushon is an indicator variable for the Cowbrush being installed and active (=1) or not (=0), Month is an indicator variable for month of the year (1 through 12), Month*Brushon is an interaction term between Brushon and Month, Re is a complex error term, where R is a correlation matrix where an autoregressive(1) correlation is estimated between daily milk weights within cow and e is a normally distributed random error term.

The variable Brushpen is an indicator for pen 27 and 30 where the Cowbrushes were installed. The variable Brushon is always equal to 0 for the control pens and switches from 0 to 1 at the day that the Cowbrushes went live. The variables Month and Month*Brushon allow an analysis of the daily milk production in each of the month since to go-live date of the Cowbrushes. The complex error term Re is a combination of a within cow correlation matrix and a random error term. With this repeated measures regression model, within cow correlation of observed milk weights is corrected for in the complex error term. Based on our previous work, an autoregressive (1) correlation was chosen. This correlation structure assumes that with increasing time distance between two milk weights in a cow, the correlation between these milk weights diminishes.

Least square means for monthly average daily milk production were calculated from the final regression model for each parity group. Least square means and standard deviations were plotted. All analyses were done using SAS version 9.2 (SAS Institute Inc., Cary, NC). The program used to analyze the data is shown in Appendix 4. A significance level of 5% was used throughout the study.

Results

Descriptive data

As soon as the Cowbrushes were installed, cows in both pens started using the brushes. Cows used the brushes intensively. Pictures of the Cowbrushes in use and a video of a cow using the brush are shown in Appendix I and II.

In Table 1, cow characteristics are shown for the cows in the study at the start of the cow brush study. Both Cowbrush pens and their respective controls were more or less identical with regard to the important cow characteristics.

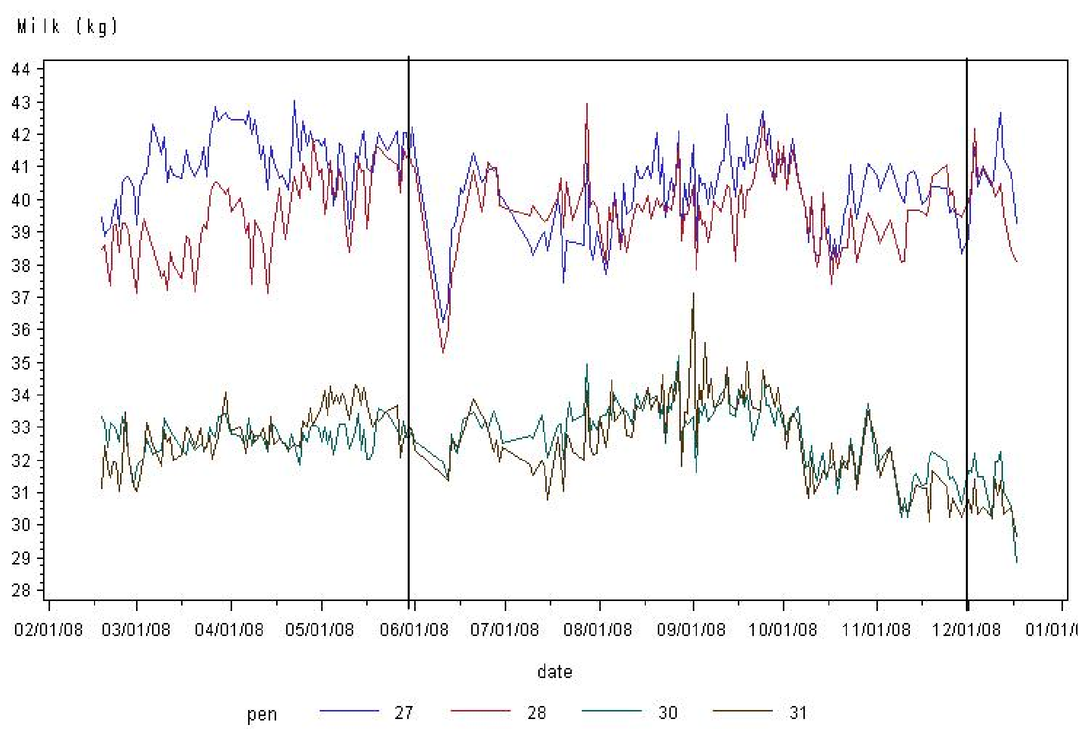
Table 1. Cow characteristics at the start of the study. DIM is days in milk, LACT is lactation number, ME305 is mature equivalent milk production in 305 days in pounds, MILK is daily milk in pounds, LS is linear score and NMAST is the number of mastitis cases per lactation.

PEN	BRUSH	#COW	Av DIM	Av LACT	AvME305	Av MILK	Av LS	AvNMAST
27	Yes	102	164	2.8	26347	92.6	2.8	1
28	No	103	180	3	26418	90.7	3.2	1.2
30	Yes	101	149	1	23202	72.8	2	1
31	No	101	161	1	23600	72.2	1.9	1

Daily milk weights over the data collection period are shown for each of the four pens in Figure 1. Two vertical lines in the Figure 1 indicate the start and the end of the 6 months data collection period. The graphs show no obvious change in daily milk production during the study period. Although these are raw data, no obvious differences between the Cow brush pens (27 and 30) and the control pens (28 and 31) are visible from the graph.

Figure 1 shows a daily milk production drop in all four pens, but particularly in the multi-para pens (27 and 28) in early June. Production in these pens dropped approximately 5 kg per day in both pens. In the second week of June, a severe heat spell was present in Upstate New York, depressing feed intake and reducing daily milk production. Temperature data for the weather station in Scipio are shown in Appendix III.

Figure 1. Daily milk production from February 15, 2008 to December 15, 2008 in the four study pens. Pen 27 and 28 are multi-para cows, Pen 30 and 31 are first lactation cows.



Statistical analyses

Statistical analysis of the data was done separately for first lactation, second lactation cows and multipara as the shape of the lactation curve is quite different between these three groups. A total of 88,567 daily milk weights from 1217 cows were available for analysis. The distribution between the three lactation groups is shown in Table 2. The goodness of fit results of the regression models for all three lactation groups (1, 2 and 3+) are also presented in Table 2. The within cow correlation estimate between subsequent daily milk weights was high and for all lactation groups over .80. Residual variance increased with increasing lactation group.

Table 2. Number of observations available for analysis and Goodness of Fit results for the final regression models for the three lactation groups. AIC is Akaike's Information Criterium, AR(1) is the within cow autoregressive correlation estimate and Residual is the variance component for random error.

Lactation group	N observations	N cows	AIC	AR(1)	Residual
1	44387	619	233799	0.81	32.53
2	18697	242	105975	0.81	48.04
3+	25483	356	148112	0.83	61.99
Total	88567	1217			

In table 3, the statistical tests of the fixed effects are shown for the three lactation groups. Some important observations from this table are that in none of the three lactation groups an overall difference between the Cowbrush and Control pen was observed before the study started. Hence the pens were comparable in terms of starting production levels. Switching the Cowbrush on resulted in a significant daily milk production change in Lactation 2 animals, but not in first lactation or older lactation animals.

Table 3. Statistical tests of the fixed effects of the regression models for the three lactation groups.

	Lactation 1		Lactation 2		Lactation 3+	
Parameters	F-value	P-value	F-value	P-value	F-value	P-value
DIM	48.3	<.0001	883.3	<.0001	1056.6	<.0001
Exp(-.1*DIM)	72.2	<.0001	10.4	0.001	12	0.0005
Month	14.9	<.0001	3.8	<.0001	4.6	0.0001
Brushpen	0.07	0.79	3	0.08	2.4	0.12
Brushon	0.01	0.92	5.2	0.02	0.6	0.44
Month*Brushon	4.5	<.0001	0.6	0.7	1.4	0.21

The most important results from table 3 is contained in the variable Brushon which showed a general trend for increased production in all three groups. However this increase in daily milk production was only statistically significant (P<.05) for Lactation 2 (table 3). In table 4, the final regression parameter estimates, the standard deviation (SD) of the parameters and the statistical significance of the parameters is shown for each of the three lactation groups.

Table 4. Parameter estimates, standard deviation (SD) and statistical significance for the three lactation groups.

		Lactation 1			Lactation 2			Lactation 3+		
Parameter		Estimate	SD	P-value	Estimate	SD	P-value	Estimate	SD	P-value
Intercept		32.0485	0.3541	<.0001	47.0857	0.7391	<.0001	47.8022	0.592	<.0001
Days in Milk DIM)		-0.008	0.001162	<.0001	-0.05676	0.001926	<.0001	-0.05347	0.00196	<.0001
exp(-.1*DIM)		298.7	34.6996	<.0001	85.552	27.396	0.0018	77.5618	19.4389	<.0001
Brushpen yes vs no		0.06337	0.2391	0.791	-0.7405	0.4346	0.0884	0.653	0.4921	0.1845
Brushon yes vs no		0.1075	0.4893	0.8262	0.963	1.0123	0.9500	0.5062	0.8734	0.5622
Month	2	1.6677	0.416	<.0001	2.0979	0.8299	0.0117	1.9439	0.7342	0.0082
Month	3	2.0701	0.3842	<.0001	2.2515	0.7918	0.0046	1.5972	0.6811	0.0192
Month	4	1.7717	0.3744	<.0001	2.0044	0.782	0.0105	1.3741	0.661	0.0378
Month	5	2.0643	0.3711	<.0001	2.3627	0.7738	0.0023	1.8153	0.6536	0.0056
Month	6	1.5515	0.395	<.0001	1.5627	0.8191	0.0568	1.5023	0.6933	0.0305
Month	7	0.8572	0.398	0.0314	0.08813	0.8274	0.9152	0.2261	0.6912	0.7436
Month	8	1.2222	0.3839	0.0015	-0.2026	0.8093	0.8024	-0.3983	0.6631	0.5481
Month	9	3.2069	0.3743	<.0001	0.7862	0.7869	0.3181	0.05113	0.6379	0.9361
Month	10	1.5864	0.353	<.0001	-0.1586	0.7563	0.8339	-0.1151	0.5964	0.847
Month	11	0.01912	0.2999	0.9492	-0.2731	0.6495	0.6742	-0.859	0.4786	0.073
Month	12	Base		.	Base	.	.	Base		
brushon*Month	5	-0.4698	0.5485	0.3917	-0.7403	1.11	0.5048	-0.7424	0.971	0.4446
brushon*Month	6	0.0891	0.5486	0.871	-0.4138	1.1291	0.714	-1.6063	0.9878	0.1039
brushon*Month	7	0.6959	0.5537	0.2088	-0.02754	1.1325	0.9806	-1.8146	0.9731	0.0622
brushon*Month	8	0.8667	0.5345	0.105	0.5932	1.1013	0.5902	-1.0039	0.9269	0.2788
brushon*Month	9	-1.0354	0.5184	0.0458	0.3686	1.0693	0.7303	0.2764	0.896	0.7577
brushon*Month	10	-0.2995	0.4948	0.545	0.821	1.0322	0.4264	-0.7522	0.8409	0.3711
brushon*Month	11	-0.4974	0.4175	0.2336	0.242	0.8825	0.7839	-0.4935	0.6821	0.4694
brushon*Month	12	Base		.	Base	.	.	Base		

The resulting estimated daily milk production curves for the three lactation groups are shown in Figures 2A,B,C.

Figure 2A. Estimated least square means daily milk production in first lactation animals. The Cowbrush went live on 27th of May, 2008.

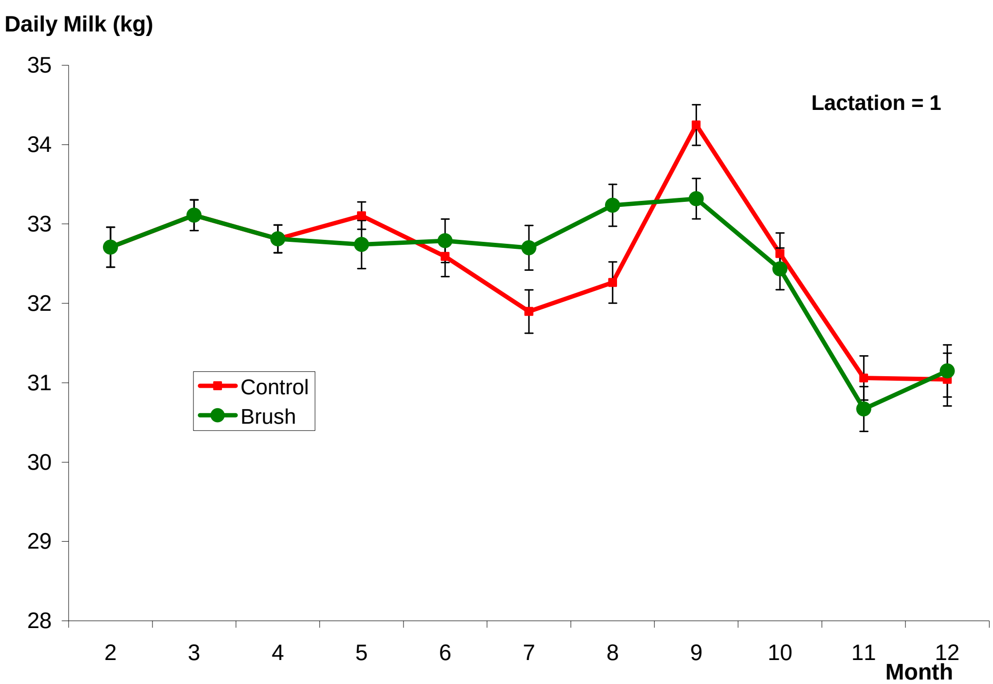


Figure 2B. Estimated least square means daily milk production in second lactation animals. The Cowbrush went live on 27th of May, 2008.

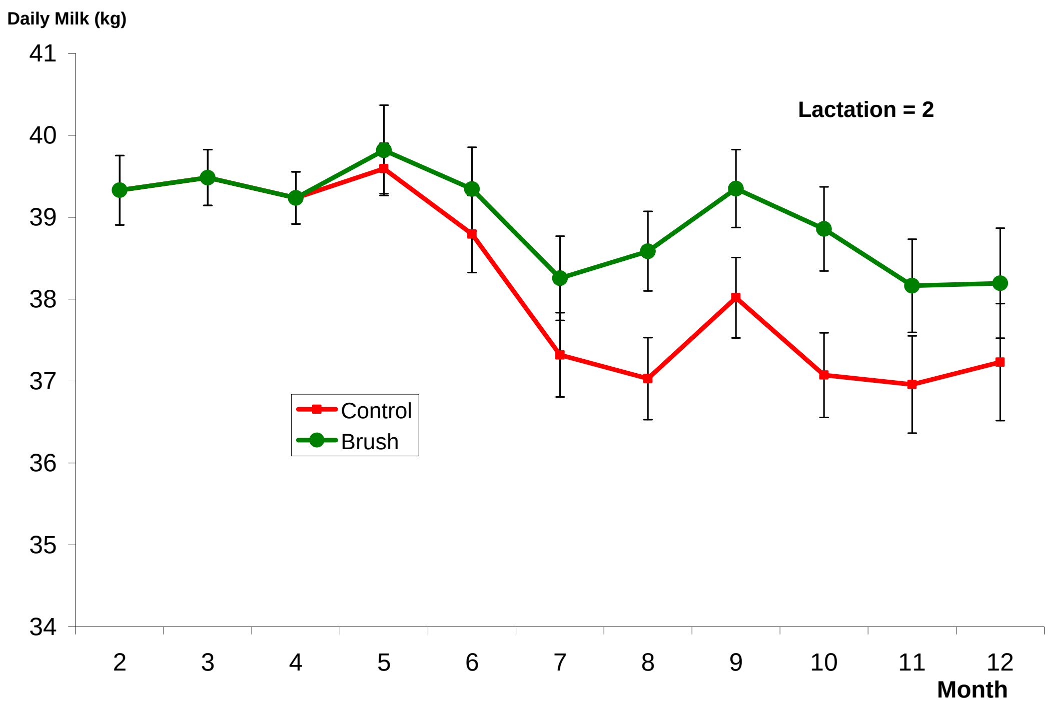
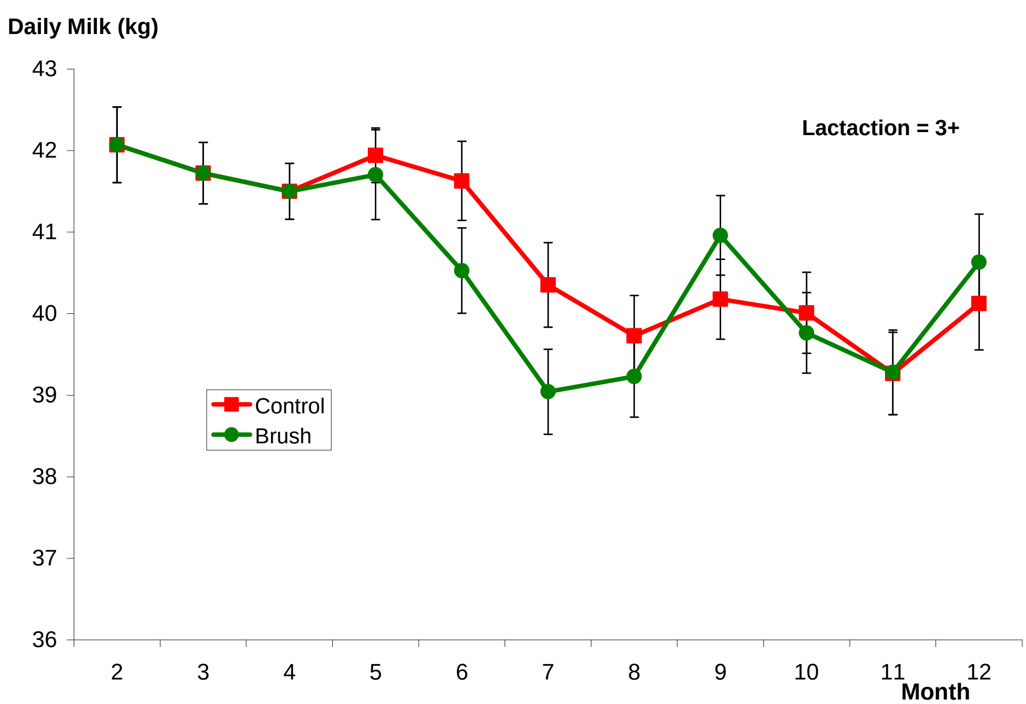


Figure 2C. Estimated least square means daily milk production in third and greater lactation animals. The Cowbrush went live on 27th of May, 2008.

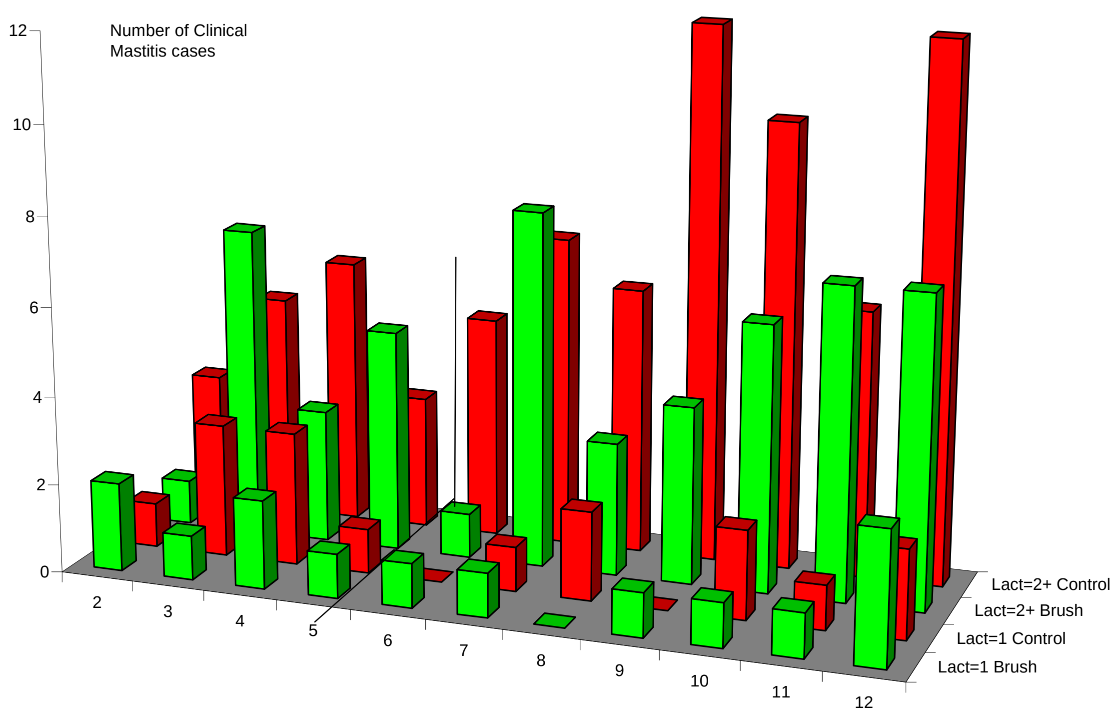


These graphs show for first lactation animals and older lactation animals that no clear consistent difference in daily milk production was present between Cowbrush pens and Control pens (figure 2A and figure 2C respectively). For second lactation animals a difference of approximately 3.5% (1 kg) of milk per day is present between Cowbrush and Control animals. The difference was smaller immediately after go-live of the cow brushes, but became larger and significant after a few months of use of the Cowbrush.

Clinical Mastitis cases and culture results.

The total number of cases of treated clinical mastitis was before the installation of the brushes for the first lactation pens 7 and 10 respectively and for the cows 22 and 25. After the go-live of the brushes this was 8 and 7 in the first lactation pens and 36 cases for the pen with the brushes and 58 cases for the control pen. The total days at risk for mastitis during the study period (from go-live to end of study) in the four pens was for pen 27, 20361 days, 28, 21651 days, 30, 20498 days and for pen 31, 20393 days. The number of cases of clinical mastitis per pen is shown in Figure 3. For the second and higher lactation cows the mastitis rate in the Brush and Control pen was respectively 1.77 per 1000 cow-days at risk and 2.68 per 1000 cow days at risk. This difference was statistically significant at $P<.05$.

Figure 3. Clinical mastitis cases in the four study pens. Cowbrush pens are indicated in green, the control pens in red. The Cowbrush went live on 27th of May, 2008.

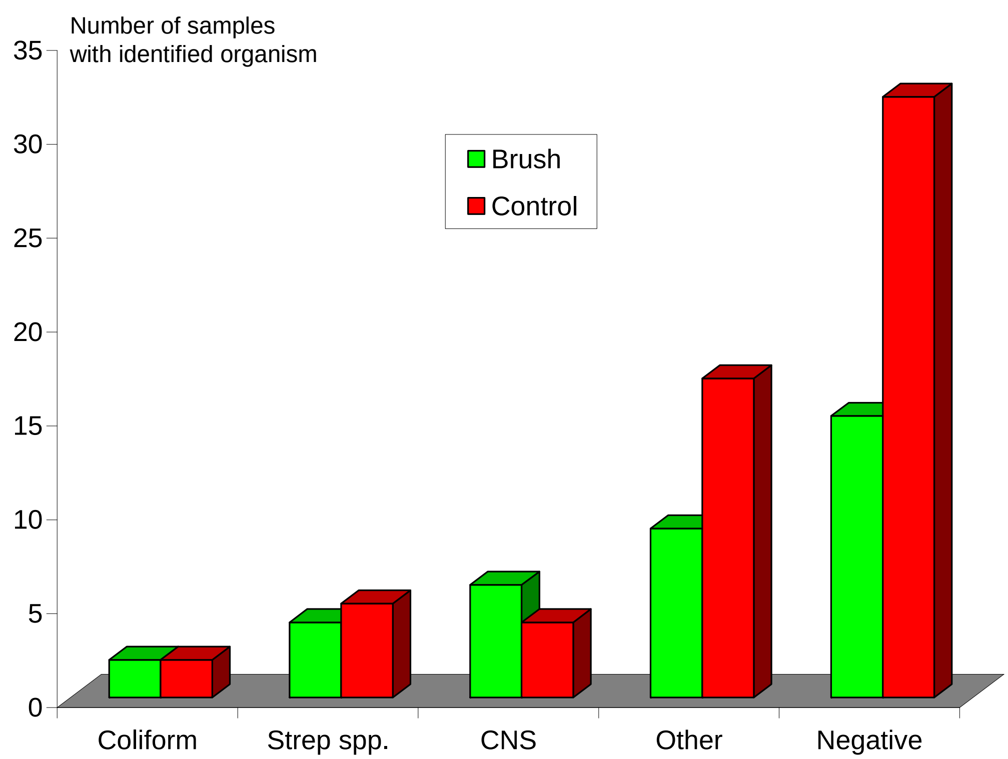


When the data were further subdivided for cows in lactation 2 and lactation 3+ it became clear that the biggest difference in clinical mastitis incidence was observed in lactation 3+. After the start of the Cowbrush, 39 clinical mastitis cases were observed in cows in lactation 3+ in the control pen while the in the Cowbrush pen 24 cases were observed in the lactation 3+ cows. In lactation 2, the number of mastitis cases were 19 and 12 in the control and Cowbrush pen respectively. These data are further summarized in Table 5. Reduction in mastitis cases in the second and higher lactation cows was 34% (22 cases) while an increase of cases of 14% was observed in first lactation (1 case).

Table 5. Mastitis incidence in the four study pens before and after go-live of the Cowbrush.

			Before go-live			After go-live				
Pen	Lactation	Cowbrush	Mastitis cases	Days at risk	Cases/1000 days at risk	Mastitis cases	Days at risk	Cases/1000 days at risk	Reduction in cases due to Cowbrush	Reduction in cases before to after go live
27	II+	Yes	22	9445	2.33	36	20361	1.77	34%	24%
28	II+	No	25	9714	2.57	58	21651	2.68		-4%
30	I	Yes	7	9289	0.75	8	20498	0.39	-14%	48%
31	I	No	10	9108	1.10	7	20393	0.34		69%
27	II	Yes	7	4310	1.62	12	8076	1.49	36%	9%
28	II	No	7	4392	1.59	19	8228	2.31		-45%
27	III+	Yes	15	5135	2.92	24	12285	1.95	33%	33%
28	III+	No	18	5322	3.38	39	13423	2.91		14%

Figure 4. Culture results from the submitted mastitis cases in the Cowbrush and Control pens. CNS = Coagulase Negative Staphylococci. Negative = culture negative



Culture results are shown in figure 4. The main causes of mastitis in the two pens were Coagulase Negative Staphylococci (CNS) and Streptococcus species (Strep spp.). No difference in relative importance of the organisms was present between the Brush and Control pens.

Discussion

In this field study, a total of four pens were used with two pens having two Cowbrushes each installed and two pens that served as contemporary controls. Although many data points provided a very precise evaluation of the differences between the pens with and without the Cowbrushes, the study design is essentially a two by two comparison. This should be kept in mind when further evaluating the observed differences between the pens.

Cows adapted well to the Cowbrushes and utilized the brushes frequently. Farm workers noticed the frequent use of the brushes and the eagerness of the cows to use the brushes. Pictures and video in Appendix I and II give a good indication of the use of the brushes throughout the study period.

Daily milk production for second lactation animals showed a significant and increasing difference in daily milk production with the time passing since installation. At approximately 6 months after installation, the difference in daily milk production stabilized at approximately 1 kg higher daily milk production (3.5%) in the cows experiencing the Cowbrushes (Figure 2B). This difference in daily milk production was not observed in the other two lactation groups. It is not clear why one lactation group of cows would show an effect due to the Cowbrush while other groups do not show this effect. While evaluating the behavior of cows with access to a mechanical brush, DeVries et al. (2007) did not report on differences between parity groups in the use of the mechanical brush. It may be hypothesized that cows that are more active and walk to use the Cowbrush are also inclined to visit the feed bunk while active. Cows being more active would also utilize ketones more efficient and may experience less reduction in feed intake due to high ketones concentration in serum. This would lead to a potential increase in daily milk yield. No obvious reason is present why this would differentially affect cows in different lactation groups. Ketosis registration in the study herd was limited to clinical cases. No difference in clinical cases of ketosis was observed in the Cowbrush and control pens (7 and 6 cases respectively).

Clinical mastitis data in cows in second and higher lactation (pens 27 and 28) showed a clear and significant difference in mastitis incidence as soon as the Cowbrushes were installed. The difference in mastitis incidence increased with increasing lactation number. We can only speculate with regards to the reasons for this decrease in mastitis cases in the pens with Cowbrushes. The initial hypothesis was that cows that are more active and walk more, are lying a shorter period of time in the stalls and thereby exposing themselves less to bacteria on the stall surface. Also the grooming behavior of the cows may lead to an overall cleaner skin in the animals with access to the Cowbrush. Although the mammary gland itself will not be groomed when using the cow brush, the tail and hind areas of the cows will be groomed (see picture 4 in appendix I) and may result in a lower exposure of the mammary gland due to general reduction of dirt on the cow. No difference was observed in the two pens with first lactation animals. The incidence of mastitis in both of these pens was very low and the power of this study to identify differences in clinical mastitis between the two first lactation cow pens was very small.

In summary, installation of the Cowbrushes resulted in an immediate increase in cow grooming behavior. Installation of the Cowbrushes resulted in either no difference in daily milk production (in lactation 1 and 3 and higher), or in an approximate 1 kg higher daily milk production in second lactation cows. Clinical mastitis was lower in pens of cows in second and higher lactation with a Cowbrush present.

References

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4. Schukken, Y.H., Grohn, Y.T., McDermott, B., McDermott, J.J., 2003. Analysis of correlated discrete observations: background, examples and solutions. Preventive Veterinary Medicine 59, 223-240.

Appendix I. Pictures of the research barn and study pens at Sprucehaven Farm and Research Center.

Picture 1. Overview of farm location and the study barn at Sprucehaven Farm and Research Center.

Study barn

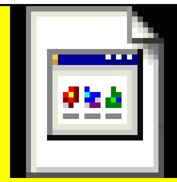
Picture 2. Cowbrush installed in Pen 30.

Picture 3. Cowbrush being used by cows in Pen 27.

Picture 4. Cowbrush being used in Pen 30.

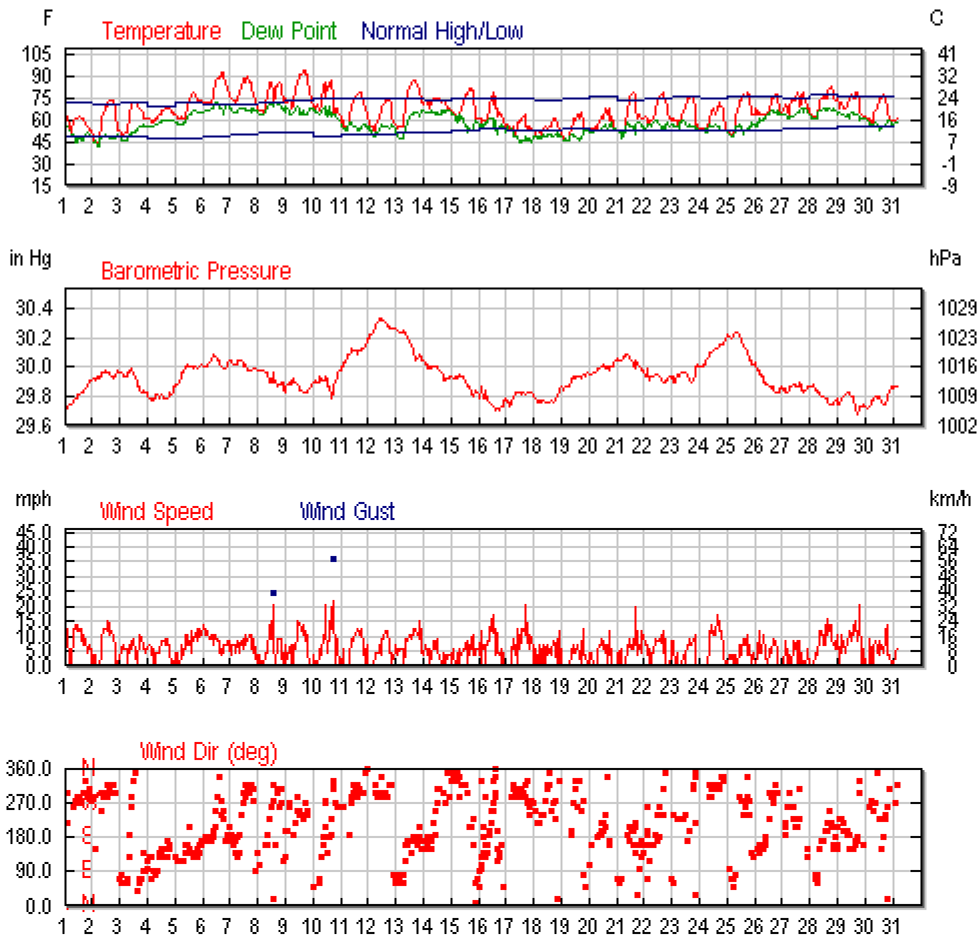
Appendix II. Embedded video of a cow using the cow brush in Pen 27.

To activate the video, click on the box below.



Very happy cow using brush.MPG

Appendix III. Temperature and weather records for Scipio, New York in June 2008



Appendix IV. SAS program used for analysis of the data.

```
Title 'Delaval cowbrush - effect on milk production';
Title2 'Data analysis Sprucehaven farms - April - July 2009';

libname dir 'C:\My Documents yhs\Trials\delaval\Cow brush\raw data milk
yield';
*filename daily 'C:\My Documents yhs\Trials\delaval\Delaval Cow
Brush\raw data milk yield\Daily Milk 12 17 2008 all data.txt';

*Read in daily milk weight data from file;
data dir.milkyld;
set work.milkyld;
run;

*Read in events data from file;
data dir.events;
set work.events;
drop nons;

proc sort data=dir.events;
by id edate;
run;

*Remove duplicate events [since events are from multiple overlapping
cowfiles];
data dir.events;
set dir.events;
lagid=lag(id);
laglact=lag(lact);
lagevent=lag(event);
lagedate=lag(edate);
if id=lagid and laglact=lact and lagevent=event and lagedate=edate then
delete;
run;
proc freq data=dir.events;
table lact;
run;

*Create file with multiple fresh data for each cow on the same data
line;
data freshdata;
set dir.events;   by id edate;
*drop laglact lagevent lagedate;
if lact>0;
if event='FRESH';
lagid=lag(id);
lag2id=lag2(id);
lag3id=lag3(id);
lag4id=lag4(id);
lag5id=lag5(id);
retain fdat1 fdat2 fdat3 fdat4 fdat5 lact1 lact2 lact3 lact4 lact5;
if first.id then do;
fdat1=.;fdat2=.;fdat3=.;fdat4=.;fdat5=.;
lact1=.;lact2=.;lact3=.;lact4=.;lact5=.;
end;
```

```
if first.id then do;fdat1=edate; lact1=lact ;end;
if lagid=id and lag2id ne id then do;fdat2=edate; lact2=lact;end;
if lagid=id and lag2id = id and lag3id ne id then do;fdat3=edate;
lact3=lact;end;
if lagid=id and lag2id = id and lag3id = id and lag4id ne id then do;
fdat4=edate; lact4=lact;end;
if lagid=id and lag2id = id and lag3id = id and lag4id = id and lag5id
ne id then do; fdat5=edate; lact5=lact;end;

run;

*Keep one data line per cow;
data freshdata;
set work.freshdata;     by id edate;
if last.id;
drop lagid lag2id lag3id lag4id lag5id lagevent lagedate laglact;
run;

*Rename variables in daily milk file;
data milkyield;
set dir.milkyld;
if var5>0;
if var6>0;
drop var1 var3;

proc datasets;
modify milkyield;
   rename var4 = id;
   rename var2 = date;
   rename var5 = pen;
   rename var6 = milklb;
   format date    MMDDYY8.;
run;

proc sort data=work.milkyield;
by id date;
run;

*Merge daily milk and events files into one file;
data milkfresh;
merge work.milkyield work.freshdata; by id;
if milklb>0;
drop event dim edate remark;
proc datasets;
modify milkfresh;
   format date fdat1 fdat2 fdat3 fdat4 fdat5 MMDDYY8.;
run;
proc sort data=milkfresh;
by id date;
quit;

*Match each milk weight to the correct lactation;
data dir.milkfresh;
set work.milkfresh;by id date;
run;
options obs=max;
data milkfresh2;
```

```
set dir.milkfresh; by id date;
lastfresh = max(fdat1, fdat2, fdat3, fdat4, fdat5);
lastfresh2 = max(fdat1, fdat2, fdat3, fdat4);
lastfresh3 = max(fdat1, fdat2, fdat3);
lastfresh4 = max(fdat1, fdat2);
lastfresh5 = fdat1;
lastlact= max(lact1, lact2, lact3, lact4, lact5);
lastlact2= max(lact1, lact2, lact3, lact4);
lastlact3= max(lact1, lact2, lact3);
lastlact4= max(lact1, lact2);
lastlact5= lact1;
dim = date-lastfresh;lacnr=lastlact;
if dim<0 then do;dim=date-lastfresh2; lacnr=lastlact2;end;
if dim<0 then do;dim=date-lastfresh3; lacnr=lastlact3;end;
if dim<0 then do;dim=date-lastfresh4; lacnr=lastlact4;end;
if dim<0 then do;dim=date-lastfresh5; lacnr=lastlact5;end;

run;

*Check data for errors;
data milkfresh2;
set work.milkfresh2;    by id date;
*options obs=5000;
options obs=max;
if dim>0;
if milklb>0;
run;
proc gplot data=work.milkfresh2;
plot milklb*dim=lacnr;
by id;
proc gchart data=work.milkfresh2;
vbar pen lacnr/discrete;
vbar milklb dim   ;
run;

data milkfresh3;
set work.milkfresh2; by id date;
if dim<0;
run;

*final data set;
data dir.finaldat;
set work.milkfresh2;by id date;
milkkg=milklb/2.2;
freshdate=date-dim;
keep id freshdate lacnr dim date pen milkkg;
run;
quit;


*statistical analysis: select cows, create dummy variables;
data finaldat2;
set dir.finaldat; by id date;
if id>0 then brushgo=17680; *brushes went in on May 27 2008;
if date-brushgo>0 then brushon=1; else brushon=0;
if pen=31 or pen=28 then brushon=0;
if pen=30 or pen=27 then brushpen=1;else brushpen=0;
```

```
if brushpen=1 then dayson=date-brushgo;else dayson=0;
if pen=30 or pen=31 then heiferpen=1;else heiferpen=0;
if lacnr=1 then heifer=1;else heifer=0;
lactcat=lacnr;
if lactcat>2 then lactcat=3;
expdim=exp(-.1*dim); *variable for regression analysis;
dimcat=int(dim/10);

*remove some odd observations in other pens;
if pen>10;
if dayson<1 then dayson=0;
if milkkg<65; *remove erroneous data points;
if dim<401; *remove cows without proper freshdate;
lagid=lag(id);
lagmilkkg=lag(milkkg);
lagdate=lag(date);
if id=lagid and milkkg=lagmilkkg and date=lagdate then delete; *some
duplicate entries;
run;

*Descriptive analysis;
data descranal;
set work.finaldat2;by id date;
mth=month(date);

proc gchart data=descranal;
vbar mth / discrete;
run;
proc gplot data=finaldat2;
*plot date*brushon;
plot milkkg*date=pen;
run;
proc sort data=finaldat2;
by date pen;
run;
proc means data=finaldat2 noprint;
var milkkg;
by date pen;
output out=milkmean mean=kgmean;
run;
data milkavg;
set work.milkmean;
proc gplot data=milkavg;
*plot date*brushon;
plot kgmean*date=pen;
symbol interpol=join;
run;

proc freq;
*tables pen lacnr heifer;
tables dimcat;
tables brushon*pen;
run;

proc gchart data=work.finaldat2;
vbar milkkg /midpoints=0 to 65 by 5;
vbar dim /midpoints=0 to 400 by 20;
```

```
run;
quit;

*Mixed linear models;
proc mixed data=finaldat2 noclprint;
class pen lactcat id;
model milkkg = lactcat dim expdim lactcat*dim lactcat*expdim heiferpen
brushpen brushon
heiferpen*brushon /solution;
repeated /subject=id type=ar(1) ;
*lsmeans brush*brushon;
run;


proc mixed data=finaldat2 noclprint;
class pen lactcat id dimcat;
model milkkg = lactcat dimcat lactcat*dimcat heiferpen brushpen brushon
/solution;
repeated /subject=id type=ar(1) ;
lsmeans lactcat*dimcat;
run;

*heifers only;
title3 'Heifers only';
Data finaldat3;
set work.finaldat2;
if lacnr=1;
if pen>28;
mth=month(date);
proc freq;
tables pen*brushpen;
tables pen*brushon;
tables mth*brushon;
proc mixed data=finaldat3 noclprint;
class id mth ;
model milkkg = dim expdim mth brushpen brushon brushon*mth/solution;
repeated /subject=id type=ar(1) ;
*lsmeans brushon*mth;
run;

*second lactation only;
Title3 'second lactation only';
Data finaldat4;
set work.finaldat2;
if lacnr=2;
if pen<30;
mth=month(date);
proc freq;
tables pen*brushpen;
tables pen*brushon;
tables mth*brushon;
proc mixed data=finaldat4 noclprint;
class  id lactcat mth brushon;
model milkkg = dim expdim expdim brushpen mth brushon
mth*brushon/solution;
repeated /subject=id type=ar(1) ;
lsmeans mth*brushon;
```

```
run;

*multipara only;
Title3 'Multipara (lact>2) only';
Data finaldat5;
set work.finaldat2;
if lacnr>2;
if pen<30;
mth=month(date);
proc freq;
tables pen*brushpen;
tables pen*brushon;
tables mth*brushon;
proc mixed data=finaldat5 noclprint;
class  id mth ;
model milkkg =  dim expdim  brushpen brushon mth mth*brushon/solution;
repeated / type=ar(1) subject=id ;
*lsmeans mth*brushon;
run;


*Analyse mastitis data;
title3 'Analysis mastitis data';
Data mast1;
set dir.events;
proc datasets;
modify mast1;
   rename edate = date;
   rename dim = dimevt;
   format date    MMDDYY8.;
proc sort data=mast1;
by id date;
run;

*Merge daily milk and events files into one file;
data dir.mast;
merge work.mast1 dir.finaldat; by id date;
if event='MAST' then mastoc=1; else mastoc=0;
drop remark lagid laglact lagevent lagedate;
run;

*Calculate days at risk per pen after brush on (=17680);
Data dar;
set dir.mast;by id date;
if date>17680;
if milkkg>0;
lactcat=lacnr;
if lacnr>2 then lactcat=3;
if pen>20;
proc sort;by id date;
data dar2;
set work.dar;by id date;
if first.id or last.id;
lagdate=lag(date);
lagid=lag(id);
if last.id and id=lagid then dar=date-lagdate;
if last.id and id=lagid and lagdate<17680 then dar=date-17680;
```

```
proc sort data=work.dar2;by pen lactcat;run;
proc means sum data=work.dar2;
var dar;by pen lactcat;
run;
*Calculate days at risk per pen before brush on (=17680);
Data darbef;
set dir.mast;by id date;
if date<=17680;
if milkkg>0;
lactcat=lacnr;
if lacnr>2 then lactcat=3;
if pen>20;
proc sort;by id date;
data darbef2;
set work.darbef;by id date;
if first.id or last.id;
lagdate=lag(date);
lagid=lag(id);
if last.id and id=lagid then dar=date-lagdate;
proc sort data=work.darbef2;by pen lactcat;run;
proc means sum data=work.darbef2;
var dar;by pen lactcat;
run;



*Create datafile with only mastitis cases;
data mastcases;
set dir.mast;by id date;
lagid=lag(id);
lagmilk=lag(milkkg);
lagdim=lag(dim);
lagpen=lag(pen);
if mastoc=1 and id=lagid and lagmilk>0 then do;
dim=lagdim;
pen=lagpen;
end;
if mastoc=1;if pen>0;
mth=month(date);
lactcat=lact;
if lact>2 then lactcat=3;
if pen>20;
run;

proc gplot data=work.mastcases;
plot dim*date=pen;
run;
proc freq data=work.mastcases;;
*tables pen*mth;
table pen*lactcat*mth;
run;

*Analyse culture data;
title3 'Analysis culture data';
Data cult1;
set dir.events;
proc datasets;
```

```
modify cult1;
   rename edate = date;
   rename dim = dimevt;
   format date    MMDDYY8.;
proc sort data=cult;
by id date;
run;

*Merge daily milk and events files into one file;
data dir.cult;
merge work.cult1 dir.finaldat; by id date;
if event='CULTURE' then cultoc=1; else cultoc=0;
drop lagid laglact lagevent lagedate;
run;

data cultcases;
set dir.cult;by id date;
lagid=lag(id);
lagmilk=lag(milkkg);
lagdim=lag(dim);
lagpen=lag(pen);
if cultoc=1 and id=lagid and lagmilk>0 then do;
dim=lagdim;
pen=lagpen;
end;
if cultoc=1;if pen>0;
mth=month(date);
run;

proc gplot data=work.cultcases;
plot dim*date=pen;
run;
proc freq;
tables pen*mth;
tables remark*pen;
run;
quit;


*Analysis of ketosis data;


title3 'Analysis ketosis data';
Data ket1;
set dir.events;
proc datasets;
modify ket1;
   rename edate = date;
   rename dim = dimevt;
   format date    MMDDYY8.;
proc sort data=ket1;
by id date;
run;

*Merge daily milk and events files into one file;
data dir.ketosis;
merge work.ket1 dir.finaldat; by id date;
```

```
if event='KETOSIS' then ketoc=1; else ketoc=0;
drop remark lagid laglact lagevent lagedate;
run;

*Calculate days at risk per pen;
Data dar;
set dir.ketosis;by id date;
if date>17680;
if milkkg>0;
lactcat=lacnr;
if lacnr>2 then lactcat=3;
if pen>20;
proc sort;by id date;
data dar2;
set work.dar;by id date;
if first.id or last.id;
lagdate=lag(date);
lagid=lag(id);
if last.id and id=lagid then dar=date-lagdate;
if last.id and id=lagid and lagdate<17680 then dar=date-17680;
proc sort data=work.dar2;by pen lactcat;run;
proc means sum data=work.dar2;
var dar;by pen lactcat;
run;

*Create datafile with only ketosis cases;
data ketcases;
set dir.ketosis;by id date;
lagid=lag(id);
lagmilk=lag(milkkg);
lagdim=lag(dim);
lagpen=lag(pen);
if ketoc=1 and id=lagid and lagmilk>0 then do;
dim=lagdim;
pen=lagpen;
end;
if ketoc=1;if pen>0;
mth=month(date);
lactcat=lact;
if lact>2 then lactcat=3;
if pen>20;
run;

proc gplot data=work.ketcases;
plot dim*date=pen;
run;
proc freq;
*tables pen*mth;
table pen*lactcat*mth;
run;
quit;
```