European Innovation Partnership (EIP) Wales

Implementing dynamic milk parlour testing to improve udder health

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1. Executive Summary

Wales has a long tradition in cost-effective, high quality milk production, while respecting the environment. The European Innovation Partnership in Wales funded this project, where four Welsh dairy farms had regular dynamic milk tests, in order to identity any issues surrounding the function of the milk parlour, milking routine, teat condition and common agents that caused mastitis. During this 12 month project, intervention was recommended by the lead clinician of the project and the results were analysed by using multi-level mixed effects regression. The decision on whether to intervene or just to observe, was based on randomisation of participants and the data analysis was implemented through stepped wedge analysis.

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
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2. Abbreviations and key words

ACR – Automatic Cluster Remover
AMU – Antimicrobial Usage
BACTO – Bulk tank bactoscan
BTSCC – Bulk tank somatic cell count
CI – Confidence Interval
Coag. - Coagulase
DCT – Dry cow therapy
Explanatory Variable – a measurable parameter that affects the outcome
ICSCC – Individual cow somatic cell counts
kPa – kilo-pascal
LMT – Long milking tube
LPT – Long pulsation tube
MAST – Clinical case of mastitis
msec – milli-second
N/A – Not applicable
NSF – No significant growth
Outcome Variable – a measurable result of a study
SCC - Somatic cell count
TMR – Total mixed ration
TS – Teat score
UH – Udder health

3. Introduction

The objective of the project was to assess the overall udder health of the herd, as expressed by specific outcome variables. This took place by measuring specific explanatory variables before and after intervention.

The reasoning behind this project was the need for dairy farms in Wales and the rest of the UK to constantly improve the quality of milk sold, adding continuous pressure on dairies to reduce antibiotic use and improve health. As consumers of milk, milk products and meat are more aware, and to some extent growing critical of the livestock industry, there needs to be an early warning system for milk producing farms to identify stress factors that if left unchecked will encourage full scale udder health issues. In the same vein, the world-wide need for sensible use of antibiotics and reduction in their use, leave very few options to herd managers when it comes to tackling udder health issues. For the most progressive dairies prevention of mastitis is key.

4. Participants

This project lasted 12 months and started in July 2020 and ended in June 2021. During that period, there were bi-monthly visits to each of the participants to carry out dynamic tests, teat score and teat measure. Two of the farms started their visits in July 2020 and the remaining two in August 2020.

The four participant farms were:

a. Dyfrig Davies or WP Thomas & Son, Berllan Dywyll, Llangathen

This is a 245 dairy cow herd, pedigree Holstein, autumn block calving between August and October, rearing own replacements that are regularly genomically tested to identify the most suitable to breed. Sexed semen is also used.

Cows are milked twice daily through a 16:32 swingover herringbone high-line parlour. The average daily milk yield at peak, expressed as the arithmetic mean is 39 litres per cow per day. The 305-day milk yield is 10,323 litres. Part of the milking routine includes pre and post dipping.

During the winter housing, milking cows are kept in cubicles, with mattresses and sand as bedding. Cows graze grass in the summer and are fed through a TMR during the winter. Concentrate feed is added in the parlour feeders.

b. D&L Morgan, Twyn farm, Nantgaredig

This is a 180 dairy cow herd of Friesian and Jersey crosses, early spring calving between February and March, rearing own replacements.

Cows are milked twice daily through a 20:40 swingover herringbone high-line parlour. The average daily milk yield at peak, expressed as the arithmetic mean is 26 litres per cow per day. The 305-day milk yield is 7,641 litres. Part of the milking routine includes pre and post dipping.

During the winter housing, milking cows are kept in cubicles, with mats and sawdust as bedding. Cows graze grass in the summer and fed round-bale silage during the winter. Concentrate feed is added in the parlour feeders.

c. Dolau Limited, Godor farm, Nantgaredig

This is a 500 dairy cow herd, of British Friesians and Holstein cows. They are calving all year round. All animals are put to beef bulls and replacement calved heifers are purchased throughout the year.

Cows are milked twice daily through a 24:48 swingover herringbone high-line parlour. The average daily milk yield, expressed as the arithmetic mean is 29 litres per cow per day. The 305-day milk yield is 8,652 litres. Part of the milking routine includes pre and post dipping.

During the winter housing, milking cows are kept in cubicles, with mats and sawdust as bedding. Cows graze grass in the summer and are fed forage during the winter. Concentrate feed is added in the parlour feeders.

d. Owens, Cwmhowel farm, Llanon

This is an 80 dairy cow herd of British Friesians. Cows are averaging 18 litres per cow per day, expressed as the arithmetic mean. They calve all year round and all animals are bred to beef bulls, while replacement heifers are purchased throughout the year.

Cows are milked twice daily through a 12:12 doubled-up low-line parlour. The average daily milk yield, expressed as the arithmetic mean is 24 litres per cow per day. The 305-day milk yield is 7,197 litres. Part of the milking routine includes pre and post dipping.

During the winter housing, milking cows are kept in cubicles, with mat and straw as bedding. Cows graze grass in the summer and are fed grass silage and round-bale silage during the winter. Concentrate feed is added in the parlour feeders.

All farm references and herd results for the remainder of the report will be randomised and anonymised into Farm A, Farm B, Farm C and Farm D.

5. Materials and methods

All dynamic testing visits at all participating farms were carried out by the author. The author also carried out all communication with the participating farmers, with regards to the study protocol, as well as addressing any queries that arose.

By monitoring and recording the dynamic testing results and therefore acting on veterinary recommendations, the participating farms may reduce the incidence of subclinical and clinical mastitis, bactoscan level, as well as their overall antimicrobial use. The monitored results that can significantly improve udder health, may subsequently be replicated on other farms to bring benefits to the wider, Welsh dairy industry. In particular, the hypothesis of this project is that improvements in the bulk tank results and herd mastitis incidence will be the outcome of implementing a specific set of interventions that are based on recommendations of the lead vet. These interventions will at first stage affect the findings of the dynamic testing. This project's assumption is that superior dynamic testing results will turn into improved teat scoring and then healthier teats will result into reduced clinical and subclinical mastitis, as well as a reduction in the bulk tank somatic cell count and bulk tank bactoscan.

There were the following four categories of variables examined in this project, interventions, dynamic testing outcomes, secondary outcomes and primary outcomes. An outline of the four variable categories can be found below and a more detailed elaboration on the four variable categories can be found in the next section of this report.

Interventions are explanatory variables and the following list shows the various actions available as recommended by the lead veterinary surgeon. The decision on which of these interventions to implement, depended on the findings of each dynamic testing, teat measuring, as well as the results of the bacteriology and sensitivity testing. Interventions were applied as a package, tailored to the findings of each farm and not as individual actions (Table 1).

Table 1. Intervention variables

Intervention Variables
Apply pre-milking teat disinfectant
Apply post-milking teat disinfectant
Prepare and store teat disinfectant correctly
Cover every teat of every cow all year round, from the teat end to its base
Dry wipe teats before applying milk units
Detect clinical mastitis visually following fore-stripping the quarters
Detect clinical mastitis with the aid of a strip detector

Observe 60-90 seconds between preparing the teats and applying the milk clusters
Check the Automatic Cluster Remover cut-off milk flow value
Check the Automatic Cluster Remover delay between vacuum cut-off and pulling the milk clusters
Shorten long milk pipes
Remove long milk pipe constrictions
Increase vacuum reserve
Change the liners to new of the same size
Change the liners to different size to match the teat size
Clean the pulsators
Clean the long pulsation tubes
Clean the air vent of the claw of the milk units
Service the master pulsation
Bacteriology and Sensitivity to test cases of mastitis before treating them with antibiotics
Attend a veterinary medicines course
Dry cows off with selectively antibiotic dry preparations
Apply sealant in teats when drying cows off
Keep dry cow accommodation clean
Scrape the passageways regularly and fully
Bed the cubicles regularly with ample and clean material
Consider renewing the cubicles, so that they become more comfortable

The section on model variables outlines which of these interventions and when they were implemented on each participating farm (Table 7a, 7b, 7c and 7d).

Dynamic testing outcomes represent a set of variables that were affected by one or more of the interventions above. The following list shows the various dynamic testing outcomes captured, as well as their data source (Table 2).

Table 2. Dynamic testing outcome variables

Dynamic Testing Outcome Variables	**Source**
Biphasic Milk Flow	Vadia Trace Recorder
Overmilking	Vadia Trace Recorder
Poor Flow Away from The Cow	Vadia Trace Recorder
Poor Liner Fit	Vadia Trace Recorder
Liner Slip	Vadia Trace Recorder
Milk Plant Pulsation	Vadia Trace Recorder

Teat Measuring (was not included in the model)	Recorded by the author during each dynamic testing visit
Bacteriology & Sensitivity (was not included in the model)	Tested by the veterinary surgeon of the participant

Secondary outcomes list a set of variables that were affected by one or more of the dynamic testing outcomes. The following list shows the secondary outcome captured, as well as their data source (Table 3).

Table 3. Secondary outcome variable

Secondary Outcome Variable	**Source**
Teat Scoring	Recorded by the author during each dynamic testing visit

Primary outcomes represent a set of variables that were affected by one or more of the secondary outcomes. These are the outcome variables that the focus of this project was mainly interested in. The following list shows the various primary outcomes captured, as well as their data source (Table 4).

Table 4. Primary outcome variables

Primary Outcome Variables	**Source**
Bulk Tank Somatic Cell Counts	MilkMonitor© / HerdCompanion©
Bulk Tank Bactoscan	MilkMonitor© / HerdCompanion©
Clinical Mastitis Incidence (Quarter)	Recorded by the participant
Mastitis Antibiotic Treatment Use	Recorded by the participant and the participant's veterinary surgeon

The chosen statistical design for this project is the stepped wedge design. With this model we split the 12-month duration of this project into six two-monthly time periods, namely T1, T2, T3, T4, T5, T6. These six time periods for each participant formed a cluster and there were four clusters in total, C1, C2, C3, C4. In each of the time periods, each cluster received a visit at which dynamic parlour tests were carried out and other measurements were collected.

During the first time period T1, also called the baseline period, none of the herds were exposed to any intervention. During time period T2 a farm, Farm A, was selected at random to have its first package of intervention, while the remaining herds had measurements only collected. Each of the participating farms were allocated a number between 1 and 4 and the randomisation method used to select which farm will receive its first package of intervention, was based on the RANDBETWEEN function of Microsoft Excel © program, Microsoft Corporation.

Likewise, a second herd, Farm B, was randomly selected at the following time period T3 for its first package of intervention and the remaining two herds had measurements only collected. At time period T4 the third herd, Farm C, had its first package of intervention and the remaining herd had measurements only collected. The final farm, Farm D, had its first package of intervention in time period T5. All four herds had intervention applied during the final time period T6.

The following table shows the timing of control and intervention visits following randomisation on all participating farms. 0 represents no intervention and 1 represents intervention. As the various interventions were specific to each farm, the purpose of the table is not to compare farms, but to compare progress on each participating farm. Therefore, the table should be read from top to bottom, where rows are compared between them (Table 5):

Table 5. Farm visits

		Group of Clusters				
		Farm A	**Farm B**	**Farm C**	**Farm D**	
	Jul & Aug 2020	CONTROL	CONTROL	CONTROL	CONTROL	**Time Period 1 (T1)**
Step 1	**Sep & Oct 2020**		CONTROL	CONTROL	CONTROL	**Time Period 2 (T2)**
		Intervention				
Step 2	**Nov & Dec 2020**		CONTROL	CONTROL		**Time Period 3 (T3)**
		Intervention			Intervention	
Step 3	**Jan & Feb 2021**		CONTROL			**Time Period 4 (T4)**
		Intervention		Intervention	Intervention	
Step 4	**Mar & Apr 2021**					**Time Period 5 (T5)**
		Intervention	Intervention	Intervention	Intervention	
Step 5						

	May & Jun 2021	Intervention	Intervention	Intervention	Intervention	**Time Period 6 (T6)**
Sequence of Interventions		**011111**	**000011**	**000111**	**001111**	

The stepped wedge design allowed an element of randomisation to the project without significantly interfering with the day-to-day routine of a commercial farm. We would like to emphasise that the measurements were collected from individual cows, whereas the various interventions were specific to the participant and were applied at a herd level. The intention of this project was to apply the various intervening actions as a package, that were most suited to each participant and not as individual recommendations. The reporting on the results of this project is also at a herd level.

We conclude on whether dynamic milk parlour testing had an effect, by comparing time periods that interventions took place to the control visits on each farm. Multi-level mixed effects regression with farm as the random effect was the chosen statistical model, time period (T1 to T6) and the nature of the visit (Control or Intervention) for each time period were fixed effects. This computation was repeated for individual cow-level observations of each of the outcome variables of the dynamic testing group and the secondary outcome group, as well as herd-level observations of the primary outcome group.

All animals from each of the participating farms were eligible for enrolment and the total numbers enrolled are shown at the following table. Numbers without brackets are animals enrolled for dynamic testing and were checked for Biphasic Milk Flow, Overmilking, Poor Flow Away from The Cow, Poor Liner Fit, Liner Slip. Numbers in square brackets are those animals enrolled for pulsation testing. Numbers in round brackets are those animals enrolled for teat scoring. The animals enrolled for dynamic testing and those for teat scoring were not necessarily the same. The cells these numbers appear in, are consistent with Table 5, indicating whether the visit was a control or an intervention one (Table 6):

Table 6. Numbers of animals tested

		Group of Clusters				
		Farm A	**Farm B**	**Farm C**	**Farm D**	
	Jul & Aug 2020	23 [8] (76)	20 [3] (42)	51 [10] (123)	24 [6] (83)	**Time Period 1 (T1)**
Step 1	**Sep & Oct 2020**		17 [3] (36)	49 [10] (118)	22 [6] (91)	**Time Period 2 (T2)**
		31 [8] (68)				

Step 2	**Nov & Dec 2020**		18 [3] (34)	38 [10] (127)		**Time Period 3 (T3)**
		38 [8] (72)			20 [6] (76)	
Step 3	**Jan & Feb 2021**		18 [3] (28)			**Time Period 4 (T4)**
		48 [8] (66)		36 [10] (141)	6 [6] (21)	
Step 4	**Mar & Apr 2021**					**Time Period 5 (T5)**
		36 [8] (68)	18 [3] (26)	39 [10] (136)	9 [6] (22)	
Step 5	**May & Jun 2021**					**Time Period 6 (T6)**
		30 [8] (59)	19 [3] (36)	34 [10] (138)	22 [6] (29)	

6. Model Variables

This section deals with a more in-depth explanation of each variable category used in this project.

Interventions

The following table shows the control and intervention actions recommended during each visit at Farm A (Table 7a).

Table 7a. Control and intervention actions at Farm A

	Farm A					
	July 20	**October 20**	**December 20**	**February 21**	**April 21**	**June 21**
Pre-milk	CONTROL	No	No	No	No	No
Post-milk	CONTROL	No	No	No	No	No
Prep. Teat Disinf.	CONTROL	No	No	No	No	No
Teat coverage	CONTROL	Yes	Yes	No	No	No
Dry-wipe	CONTROL	No	No	No	No	No
Detect Visual	CONTROL	No	No	No	No	No
Detect in-line	CONTROL	No	No	No	No	No
60-90 sec	CONTROL	No	No	No	No	No
ACR Milk Flow	CONTROL	No	Yes	Yes	Yes	No
ACR Delay	CONTROL	No	Yes	Yes	Yes	No
Shorten LMT	CONTROL	No	No	No	No	No
LMT Restrict	CONTROL	Yes	No	No	No	No
Increase VR	CONTROL	No	No	No	No	No
Liners – Same	CONTROL	No	No	No	No	No

Liners – Match	CONTROL	No	No	Yes	Yes	Yes
Pulsators - Clean	CONTROL	Yes	No	No	No	No
LPT – Clean	CONTROL	Yes	No	No	No	No
Claw Vent – Clean	CONTROL	No	No	No	No	No
Master Pulsation	CONTROL	No	No	No	No	No
Bacti & Sensi	CONTROL	Yes	Yes	Yes	Yes	Yes
Vet Meds Course	CONTROL	Yes	No	No	No	No
Selective DCT	CONTROL	No	No	No	No	No
Teat Sealant	CONTROL	No	No	No	No	No
Dry Yard – Clean	CONTROL	No	No	No	No	No
Scrape housing	CONTROL	No	No	No	No	No
Cubicle bedding	CONTROL	No	No	No	No	No
Cubicle renew	CONTROL	No	No	No	No	No

The following table shows the control and intervention actions recommended during each visit at Farm B (Table 7b).

Table 7b. Control and intervention actions at Farm B

	Farm B					
	July 20	**September 20**	**November 20**	**January 21**	**March 21**	**May 21**
Pre-milk	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Post-milk	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Prep. Teat Disinf.	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Teat coverage	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes
Dry-wipe	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Detect Visual	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Detect in-line	CONTROL	CONTROL	CONTROL	CONTROL	No	No
60-90 sec	CONTROL	CONTROL	CONTROL	CONTROL	No	No
ACR Milk Flow	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes
ACR Delay	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes
Shorten LMT	CONTROL	CONTROL	CONTROL	CONTROL	No	No
LMT Restrict	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Increase VR	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Liners – Same	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Liners – Match	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Pulsators - Clean	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes
LPT – Clean	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes
Claw Vent – Clean	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Master Pulsation	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Bacti & Sensi	CONTROL	CONTROL	CONTROL	CONTROL	Yes	Yes

Vet Meds Course	CONTROL	CONTROL	CONTROL	CONTROL	Yes	No
Selective DCT	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Teat Sealant	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Dry Yard – Clean	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Scrape housing	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Cubicle bedding	CONTROL	CONTROL	CONTROL	CONTROL	No	No
Cubicle renew	CONTROL	CONTROL	CONTROL	CONTROL	No	No

The following table shows the control and intervention actions recommended during each visit at Farm C (Table 7c).

Table 7c. Control and intervention actions at Farm C

	Farm C					
	August 20	**October 20**	**December 20**	**February 21**	**April 21**	**June 21**
Pre-milk	CONTROL	CONTROL	CONTROL	No	No	No
Post-milk	CONTROL	CONTROL	CONTROL	No	No	No
Prep. Teat Disinf.	CONTROL	CONTROL	CONTROL	No	No	No
Teat coverage	CONTROL	CONTROL	CONTROL	Yes	No	No
Dry-wipe	CONTROL	CONTROL	CONTROL	No	No	No
Detect Visual	CONTROL	CONTROL	CONTROL	No	No	No
Detect in-line	CONTROL	CONTROL	CONTROL	No	No	No
60-90 sec	CONTROL	CONTROL	CONTROL	No	No	No
ACR Milk Flow	CONTROL	CONTROL	CONTROL	Yes	Yes	No
ACR Delay	CONTROL	CONTROL	CONTROL	Yes	Yes	No
Shorten LMT	CONTROL	CONTROL	CONTROL	No	No	No
LMT Restrict	CONTROL	CONTROL	CONTROL	No	No	No
Increase VR	CONTROL	CONTROL	CONTROL	No	No	No
Liners – Same	CONTROL	CONTROL	CONTROL	No	No	No
Liners – Match	CONTROL	CONTROL	CONTROL	Yes	Yes	Yes
Pulsators - Clean	CONTROL	CONTROL	CONTROL	No	No	No
LPT – Clean	CONTROL	CONTROL	CONTROL	No	No	No
Claw Vent – Clean	CONTROL	CONTROL	CONTROL	No	No	No
Master Pulsation	CONTROL	CONTROL	CONTROL	No	No	No
Bacti & Sensi	CONTROL	CONTROL	CONTROL	Yes	Yes	Yes
Vet Meds Course	CONTROL	CONTROL	CONTROL	Yes	No	No
Selective DCT	CONTROL	CONTROL	CONTROL	No	No	No
Teat Sealant	CONTROL	CONTROL	CONTROL	No	No	No
Dry Yard – Clean	CONTROL	CONTROL	CONTROL	No	No	No
Scrape housing	CONTROL	CONTROL	CONTROL	No	No	No
Cubicle bedding	CONTROL	CONTROL	CONTROL	No	No	No

Cubicle renew	CONTROL	CONTROL	CONTROL	No	No	No

The following table shows the control and intervention actions recommended during each visit at Farm D (Table 7d).

Table 7d. Control and intervention actions at Farm D

	Farm D					
	July 20	**September 20**	**November 20**	**January 21**	**March 21**	**May 21**
Pre-milk	CONTROL	CONTROL	No	No	No	No
Post-milk	CONTROL	CONTROL	No	No	No	No
Prep. Teat Disinf.	CONTROL	CONTROL	No	No	No	No
Teat coverage	CONTROL	CONTROL	Yes	No	No	No
Dry-wipe	CONTROL	CONTROL	No	No	No	No
Detect Visual	CONTROL	CONTROL	No	No	No	No
Detect in-line	CONTROL	CONTROL	No	No	No	No
60-90 sec	CONTROL	CONTROL	No	No	No	No
ACR Milk Flow	CONTROL	CONTROL	Yes	Yes	No	No
ACR Delay	CONTROL	CONTROL	Yes	Yes	No	No
Shorten LMT	CONTROL	CONTROL	No	No	No	No
LMT Restrict	CONTROL	CONTROL	No	No	No	No
Increase VR	CONTROL	CONTROL	No	No	No	No
Liners – Same	CONTROL	CONTROL	No	No	No	No
Liners – Match	CONTROL	CONTROL	No	No	Yes	No
Pulsators - Clean	CONTROL	CONTROL	Yes	Yes	No	No
LPT – Clean	CONTROL	CONTROL	No	No	No	No
Claw Vent – Clean	CONTROL	CONTROL	No	No	No	No
Master Pulsation	CONTROL	CONTROL	No	No	No	No
Bacti & Sensi	CONTROL	CONTROL	Yes	Yes	Yes	No
Vet Meds Course	CONTROL	CONTROL	No	No	No	No
Selective DCT	CONTROL	CONTROL	No	No	No	No
Teat Sealant	CONTROL	CONTROL	No	No	No	No
Dry Yard – Clean	CONTROL	CONTROL	No	No	No	No
Scrape housing	CONTROL	CONTROL	No	No	No	No
Cubicle bedding	CONTROL	CONTROL	No	No	No	No
Cubicle renew	CONTROL	CONTROL	No	No	No	No

<u>Dynamic testing outcomes</u>

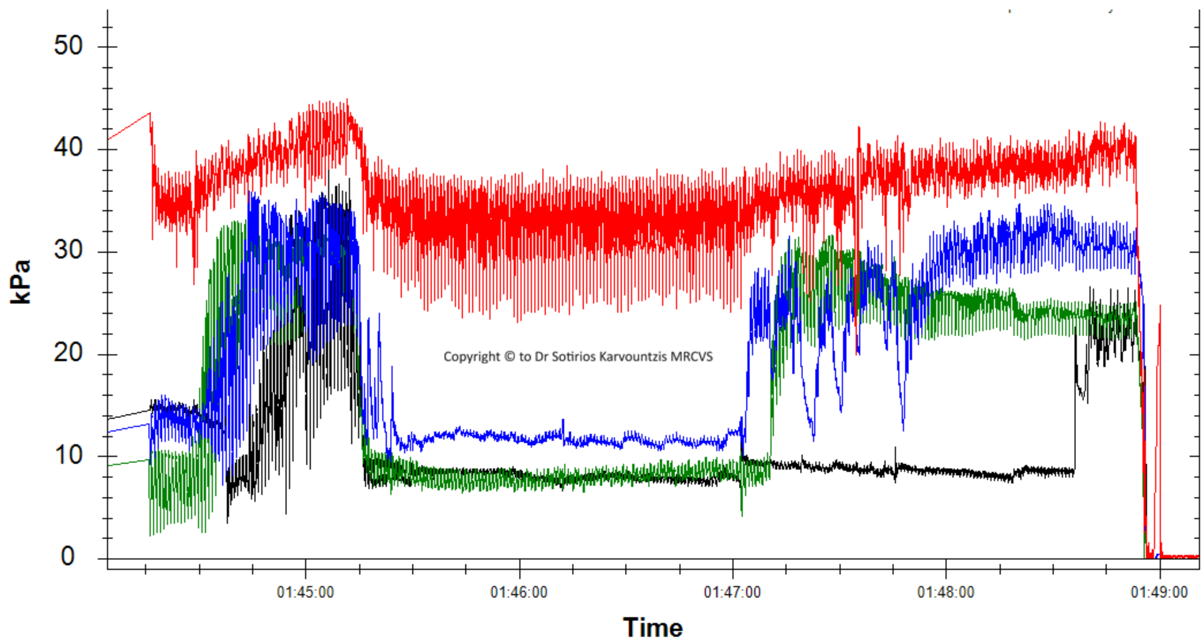
Biphasic Milk Flow

The milk-let down reflex can be described as a loop and it involves the mammary gland, the nervous system, pituitary gland, circulatory system and consists of the following parts:

- Stimulation: What defines stimulation as part of this reflex, can vary. It is usually the act of touching the cow's teat for stripping the foremilk or applying the pre-dip. On the other hand, this reflex is triggered by the sound of cake hitting the bins, while the cows enter the parlour.
- Transportation: The stimuli travel to the hypothalamus part of the brain via the sensory nerves and this results in the release of oxytocin from the posterior pituitary gland.
- Oxytocin: This is a hormone that travels from the pituitary gland through the blood vessels to the udder. There, it causes the contraction of the smooth muscles and the discharge of milk.

This procedure from stimulation until milk discharge lasts for 60-90 seconds. When we design milking routines, we need to bear in mind that once the cow is stimulated, the "clock is ticking" and we would need to attach the units within the optimum time. We accept that up to one in six cows milked may suffer biphasic milking in one or more quarters. We intervene at a herd level, when biphasic milking occurs at more than one out of every five cows milked. A vacuum trace that recorded biphasic milking is shown below (Figure 1).

Figure 1. Vacuum trace showing biphasic milking



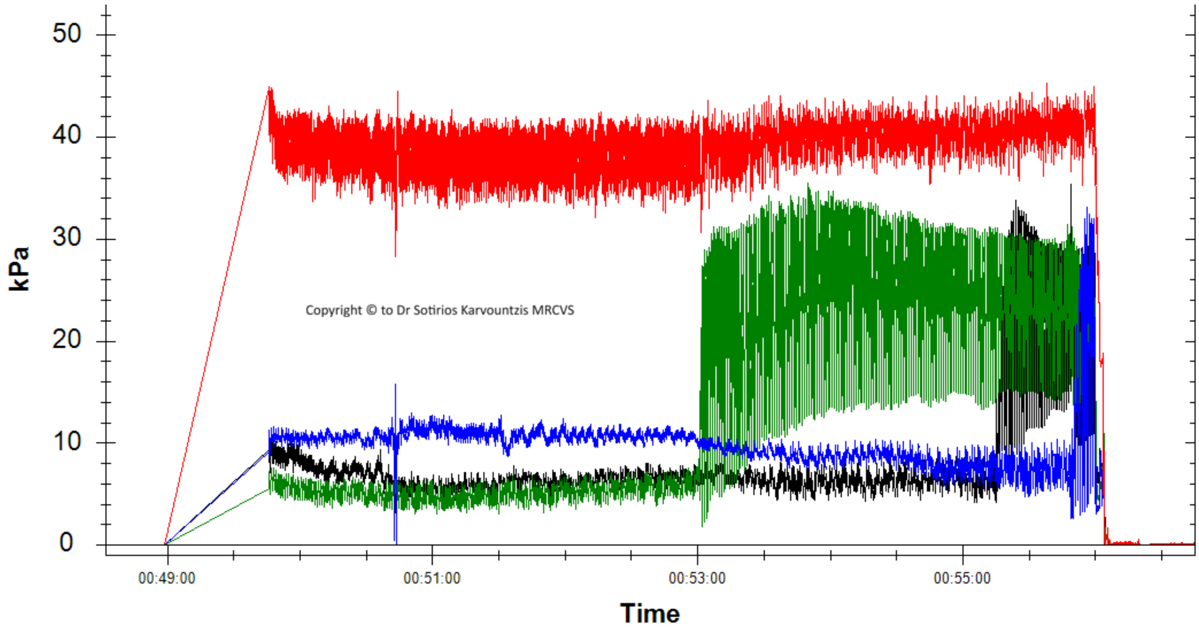
Overmilking

Overmilking is defined as the prolonged application of vacuum at the teat end, beyond a point when the high milk flow has ceased and the amount of milk extracted from the quarter is minimal.

When assessing the presence of overmilking, firstly we need to determine the number of quarters involved, as the acceptable duration of applying vacuum in the quarter beyond the end of high milk flow depends on the number of quarters involved. We accept that with only one quarter involved, durations of over 60 seconds constitutes overmilking. This becomes 30 seconds, when two or more quarters are involved.

Secondly, on a herd level we accept that up to one in six cows milked may suffer overmilking, without the need to mediate. We intervene at a herd level, when overmilking occurs at more than one out of every five cows tested. A vacuum trace that recorded overmilking is shown below (Figure 2).

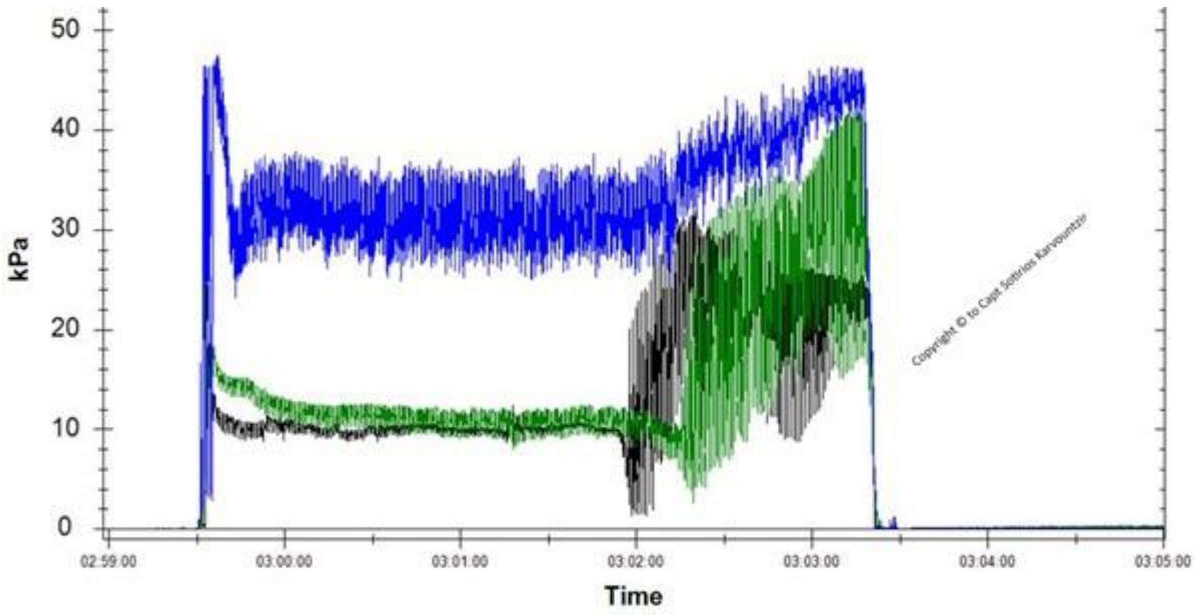
Figure 2. Vacuum trace showing overmilking



Poor Flow Away from The Cow

Poor milk flow away from the teat occurs when the vacuum at the teat-end level during the low milk flow phase at the end of milking, elevates by more than 10kPa of vacuum. This is an indication that the milk plant is struggling to shift the milk away from the teat. This in turn will lead to milk remaining close to the teat-end in a swirling motion, increasing the risk of re-entering the teat cistern and infecting the quarter. We intervene at a herd level, when such poor milk flow occurs at more than one out of every five cows milked. A vacuum trace that recorded poor milk flow away from the teat is shown below (Figure 3).

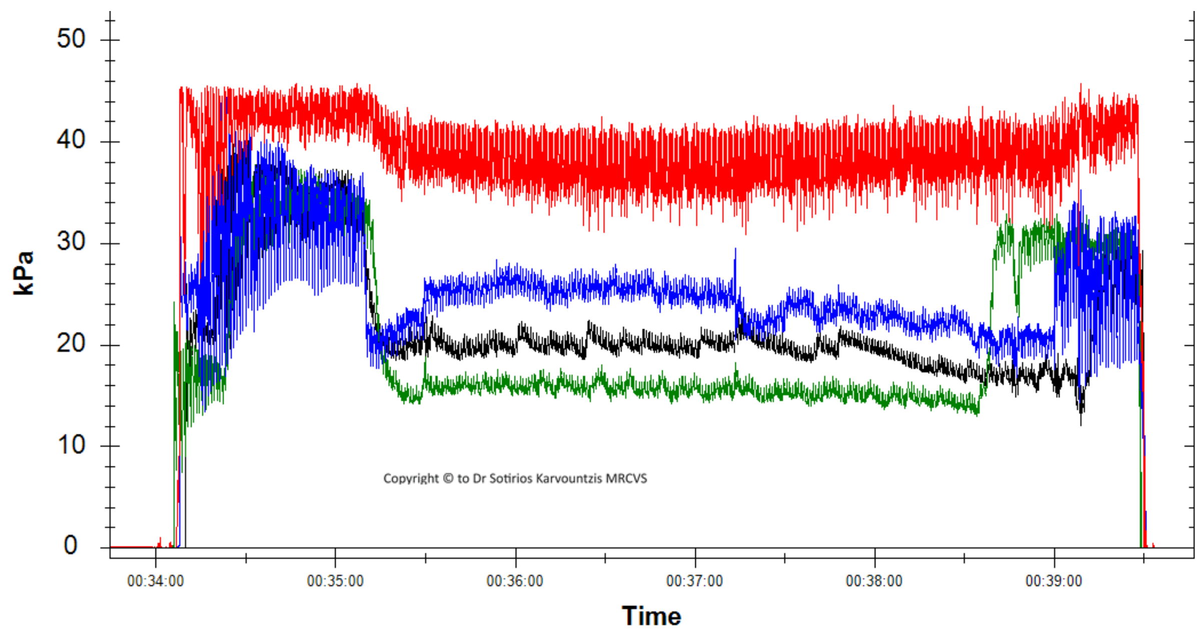
Figure 3. Vacuum trace showing poor milk flow away from the teat



Poor Liner Fit

Liner fit is measured by comparing the height and width of the barrel of the liner mouthpiece chamber against those of the cows' teats. Specifically, when the vacuum at the mouthpiece chamber is in excess of 20 kPa (while the ideal lever is 10 kPa or below), it is likely to indicate issues with liner fit. As the liners are not attached to the base of the teat properly, they increase the risk of irregular vacuum fluctuations to the teat-end and the risk of mastitis. We accept that up to one in six cows milked may suffer poor liner fit in one or more quarters. We intervene at a herd level, when poor liner fit occurs at more than one out of every five cows milked. A vacuum trace that recorded poor liner fit is shown below (Figure 4).

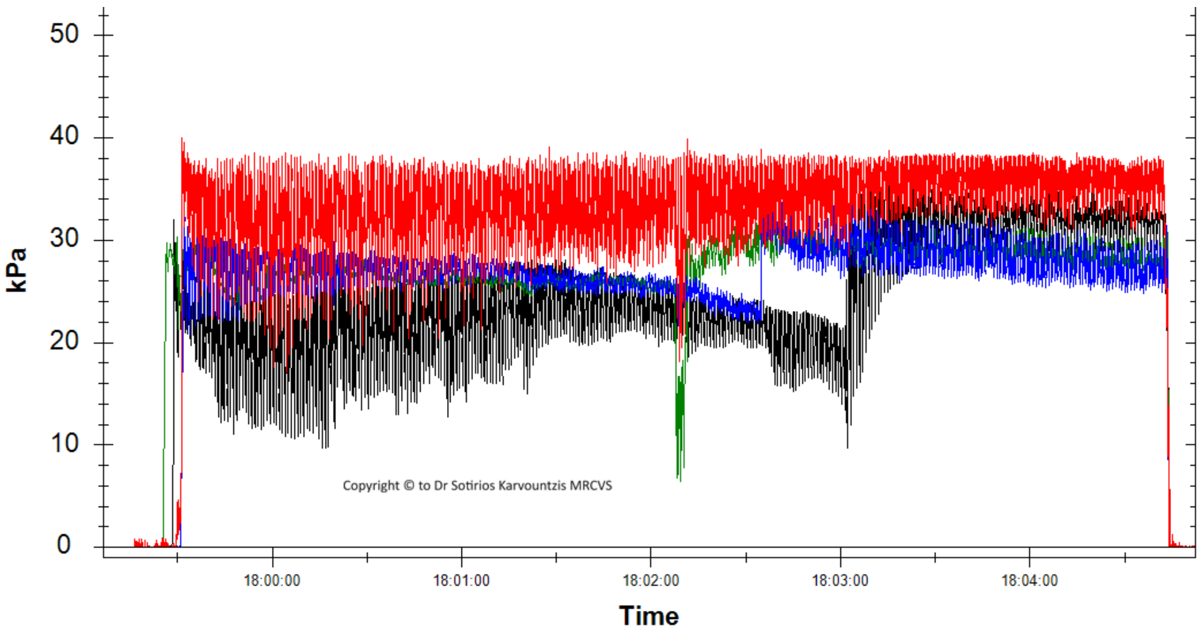
Figure 4. Vacuum trace showing poor liner fit



Liner Slip

A marked and sharp vacuum drop in all channels constitutes liner slip. The cause of this is usually two-fold, leakage of air in the system coupled with inadequate vacuum reserve, rendering the plant unable to recover to operating vacuum levels. Liner slip has far-reaching effects, from slowing milking down, to predisposing to mastitis and high SCC. We intervene at a herd level, when poor liner fit occurs at more than one out of every five cows milked. A vacuum trace that recorded liner slip is shown below (Figure 5).

Figure 5. Vacuum trace showing liner slip



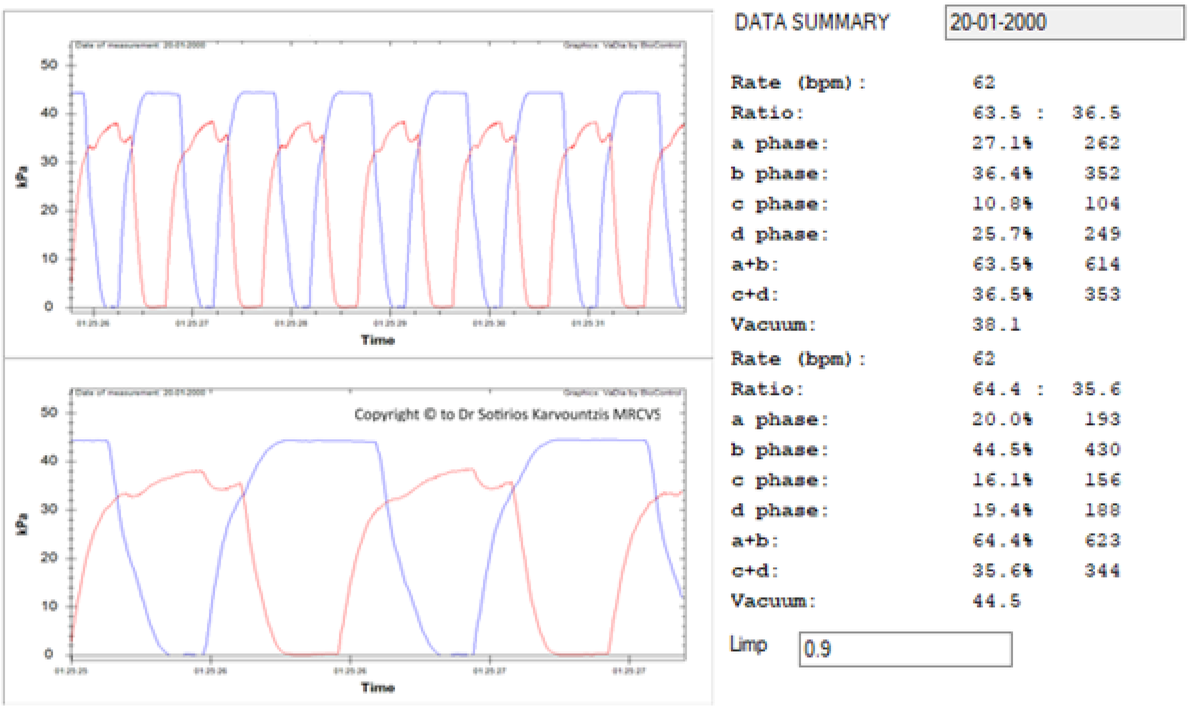
Milk Plant Pulsation

The pulsation system of the milking plant was tested by a fourth Vadia recording device, which during milking was moved to different unit, once a cow finished milking. Depending on the duration of milking and herd size, 25% to 50% of all units and their pulsators were tested at each visit. It was ensured that a different set of units and pulsators would be tested at the next dynamic test, so that by the end of the project all pulsators would be appraised. There are the following areas of interest in the pulsation system:

- Pulsation Type, expressed as alternating (2.2) or simultaneous (4.0). All participants operated their milk plants on alternating pulsation (2.2).
- Pulsation Rate, expressed as beats per minute. Verified on whether it operated according to manufacturer's instructions.
- Pulsation Ratio, expressed as a fraction indicating the milk-out phases versus the rest phases. Verified on whether it operated according to manufacturer's instructions.
- Operating vacuum, expressed in kPa. Verified on whether it operated according to manufacturer's instructions.

- Milk phases, in specific we were interested in:
    - a-phase: Vacuum surrounding the liner is increasing, forcing the teat end to open and milk extraction is commencing. We would intervene here, if this phase exceeds 165 msec.
    - b-phase: Vacuum surrounding the liner is at peak, the teat end is fully open and milk flow is at peak.
    - c-phase: Vacuum surrounding the liner is decreasing, forcing the teat end to close and milk extraction is reducing. We would intervene here, if this phase exceeds 140 msec.
    - d-phase: Vacuum surrounding the liner is at a minimum, the teat is closed. This is the rest phase of milking. We would intervene here, if this phase exceeds 250 msec.

Figure 6. A typical vacuum trace that recorded the pulsation system



Teat Measuring

At each dynamic testing visit a random sample of the milking cows, approximating 30% of the overall herd size, had their teats measured. With the aid of a set of callipers used in cattle tuberculosis testing the length and width of the back right teat of each sampled animal was recorded. The aim of this recording was complementary, in order to verify whether the liners in use were matching the average teat size of the participating herd.

Bacteriology & Sensitivity

Sterile milk samples were collected from as many as possible clinical cases and submitted to a milk laboratory, in order to better understand the pathogens involved. In particular, we were interested in four pathogens, Coliform spp, Strep uberis, Coag. +ve Staph and Staph aureus. Sensitivity was carried out, so that the best antimicrobial would be determined for a particular pathogen.

Secondary outcomes

Teat Scoring

At each dynamic testing visit, a random sample of 30% of all cows milked were examined and graded with the AHDB Teat Score system, that utilises four scores. Namely N for no ring, S for smooth ring, R for rough ring and VR for very rough ring. It is accepted that R and VR are increasing the risk of mastitis or high somatic cell count to the quarter. For the purpose of statistical analysis of this project, scores N and S were combined into result 0 indicating no significant lesions, while groups R and VR were combined into result 1 indicating lesions of some significance.

Primary outcomes

Bulk Tank Somatic Cell Counts

The number of somatic cells present in the bulk tank milk (BTSCC) is measured and expressed as the three-month rolling geometric mean in thousands of cells per millilitre of milk (x1,000 per ml). Somatic cell count is an indicator of subclinical or clinical mammary infection present.

An uninfected quarter or quarters would have very few cells present in their milk, mostly mammary epithelial cells. Infected quarters produce milk with high number of leucocytes present in it, due to the mobilisation of white blood cells stimulated by the presence of harmful bacteria in the udder.

We accept individual cow samples (ICSCC) with results of below 100,000 cells per ml are unlikely to be infected, whereas those of over 200,000 cells per ml are likely to be infected in one or more quarters. The intervention levels are different in BTSCC, as they are dependent on milk contracts. It is accepted that BTSCC over 200,000 cells per ml are often accompanied with either loss of a payment bonus or with implementation of financial penalties.

Bulk Tank Bactoscan

The number of bacteria present in the bulk tank milk is measured and expressed as the three-month rolling geometric mean in thousands of cells per millilitre of milk (x1,000 per ml). Bactoscan is an indicator of cleanliness and hygiene of milk. High levels of bacteria reduce the shelf-life of fresh milk, as well as reduce cheese yields.

It is accepted that BACTO levels over 50,000 cells per ml are often accompanied with either loss of a payment bonus or implementation of financial penalties.

Clinical Mastitis Incidence (Quarter)

The number of clinical mastitis cases per affected quarter over the 12-month duration of the project was recorded and expressed as a percentage. We accept as a separate case of mastitis, a case that occurred seven days or more from the previous one on the same quarter. The values for this parameter at a herd level can vary from zero to an infinite number, as a quarter can develop mastitis numerous times in a year. According to the AHDB Mastitis Control Plan the mean mastitis incidence for the UK was 30.3% in 2018.

Mastitis Antibiotic Treatment Use

Data were collected based on antimicrobial preparations that were purchased from the participants' nominated veterinary surgeons. These purchases were compared against all antimicrobial treatments recorded in the medicine book of each participant. Such recording is a requirement of dairy farm assurance schemes, that all dairy producers in the UK must subscribe to.

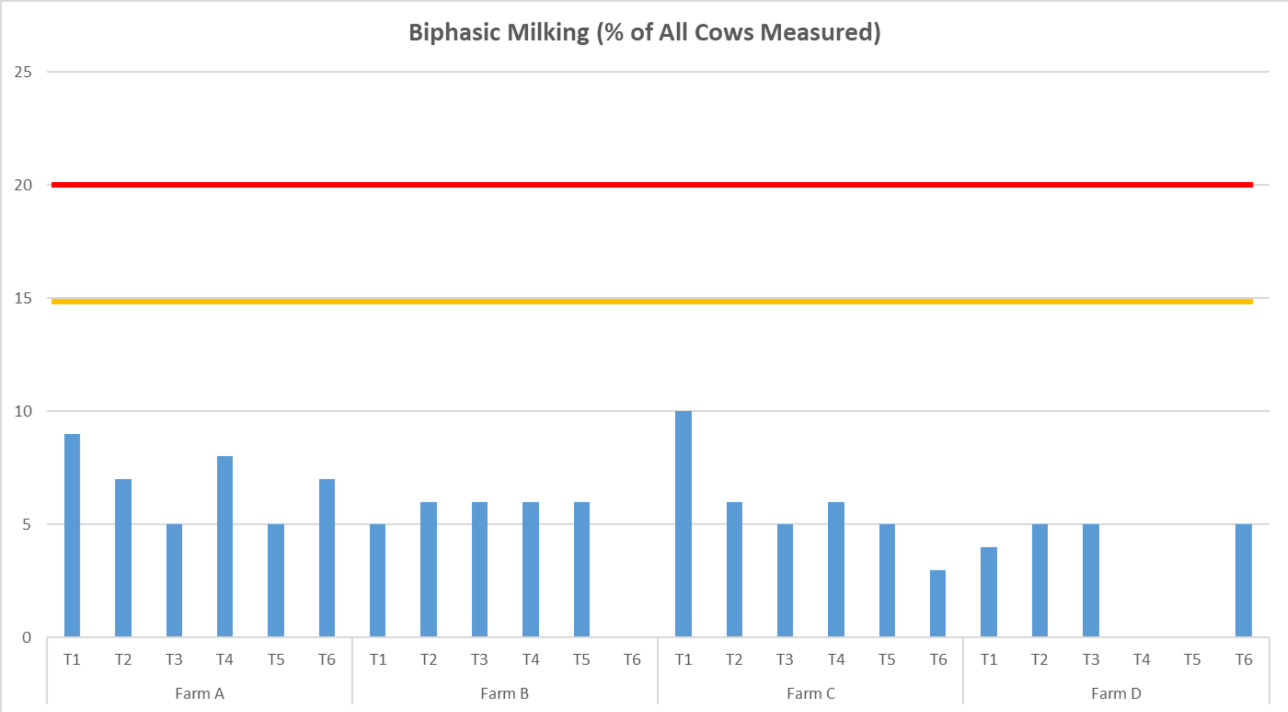
Each farm's AMU was calculated with the aid of the Antimicrobial Unit Dairy Calculator, by the University of Nottingham. In that, the total amount was entered that was used for the antimicrobial treatment of mastitis and it was expressed as milligram of antimicrobial used per kilogram of standard body liveweight (mg/kg).

7. Results

Biphasic Milk Flow

The following graph shows the incidence of biphasic milking during each dynamic testing, expressed as a percentage of all cows tested during that visit. The amber coloured line represents the monitoring level which is the level that the industry deems acceptable, whereas the red line indicates the intervention level or the level at which action is recommended (Figure 7):

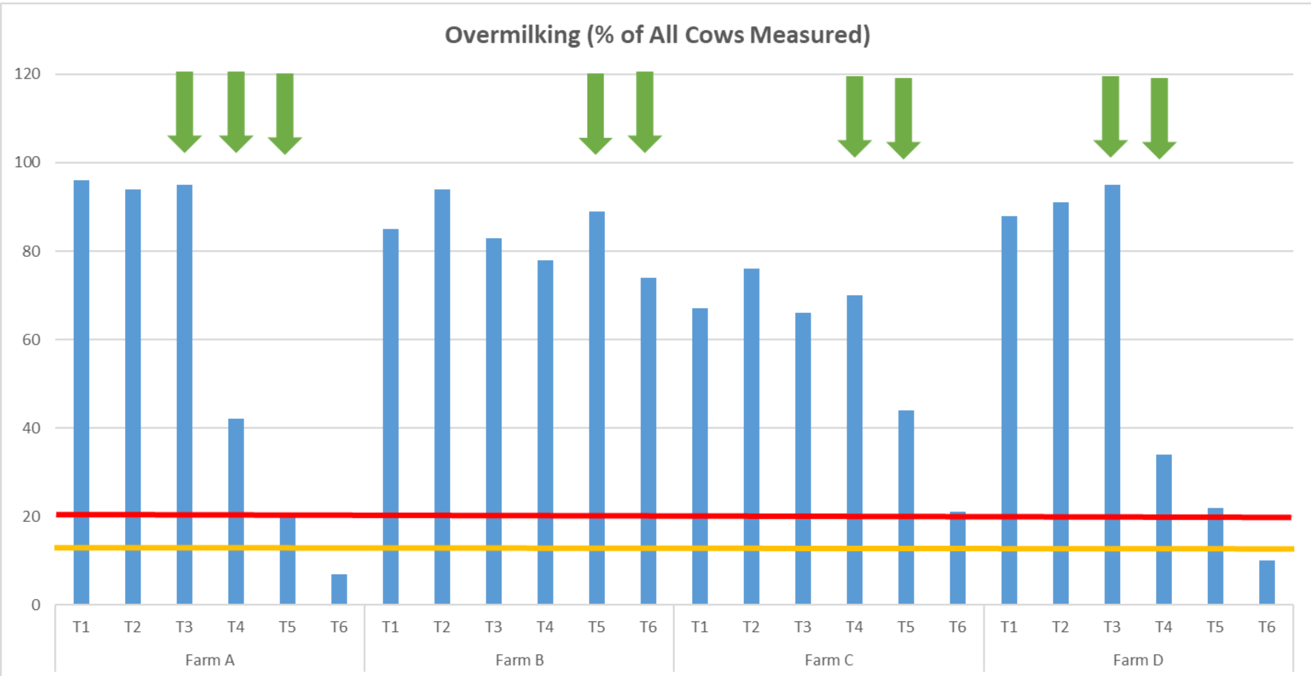
Figure 7. Incidence of biphasic milking



Overmilking

The following graph shows the incidence of overmilking during each dynamic testing, expressed as a percentage of all cows tested during that visit. The amber coloured line represents the monitoring level, whereas the red line indicates the intervention level. The green arrows indicate the time period where intervention took place. In this case, intervention addressed issues with cut-off milk flow or with delay between cutting vacuum and pulling the units off or both (Figure 8):

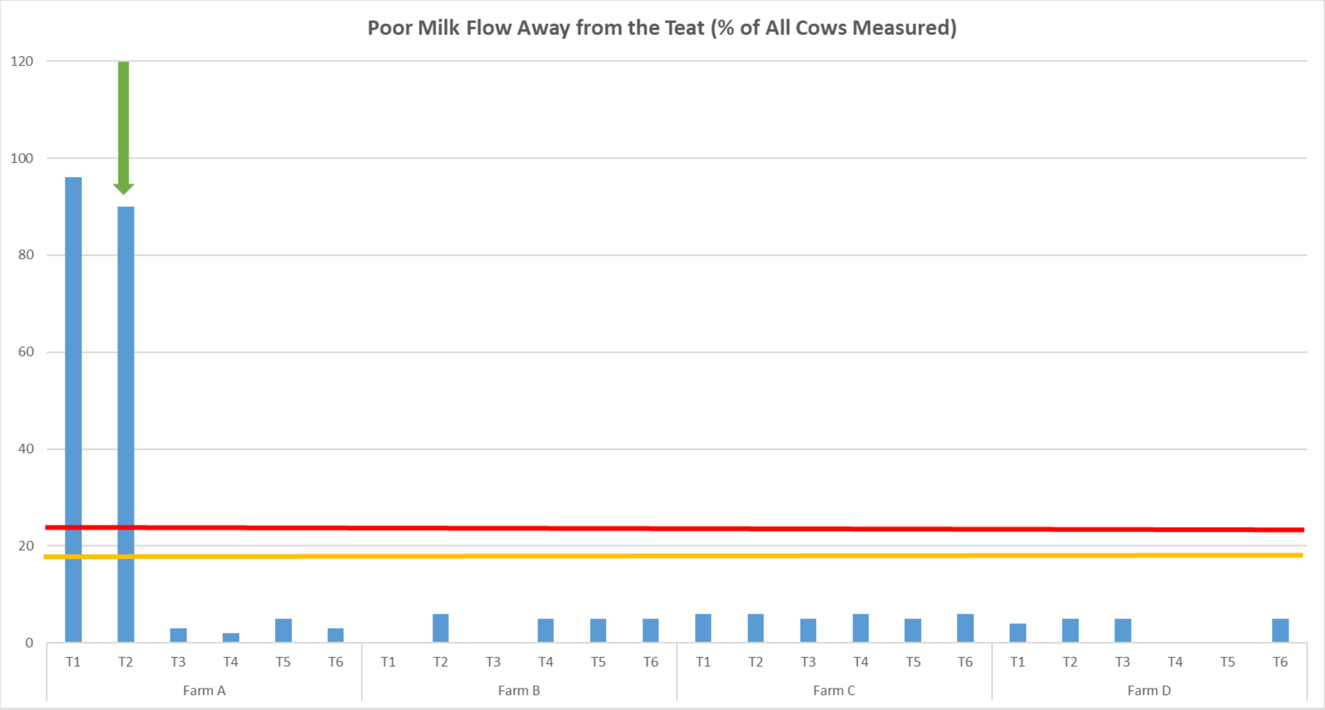
Figure 8. Incidence of overmilking



Poor Flow Away from The Cow

The following graph shows the incidence of poor flow away from the teat during each dynamic testing, expressed as a percentage of all cows tested during that visit. The amber coloured line represents the monitoring level, whereas the red line indicates the intervention level. The green arrows indicate the time period where intervention took place (Figure 9):

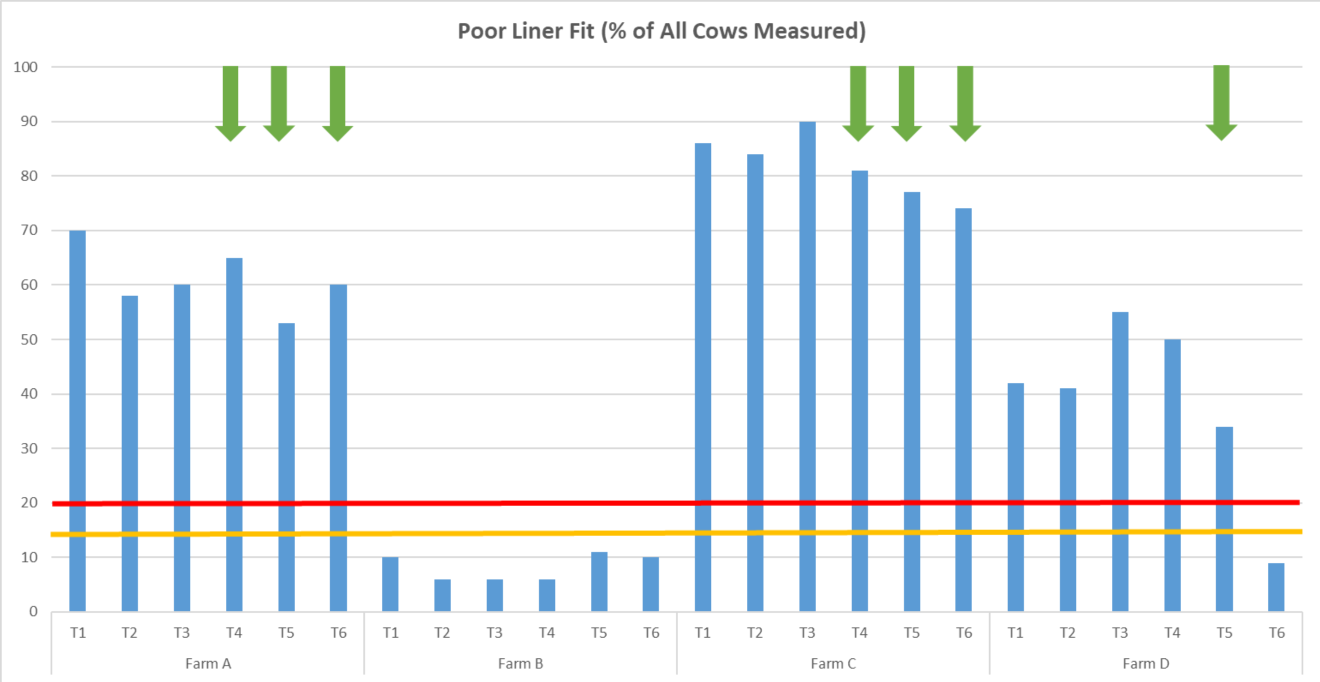
Figure 9. Incidence of poor flow away from the teat



Poor Liner Fit

The following graph shows the incidence of poor liner fit during each dynamic testing, expressed as a percentage of all cows tested during that visit. The amber coloured line represents the monitoring level, whereas the red line indicates the intervention level. The green arrows indicate the time period where intervention took place. In this case, intervention addressed issues with replacing with the same liners as the existing ones or replacing with liners to match the average teat size in the herd or both (Figure 10):

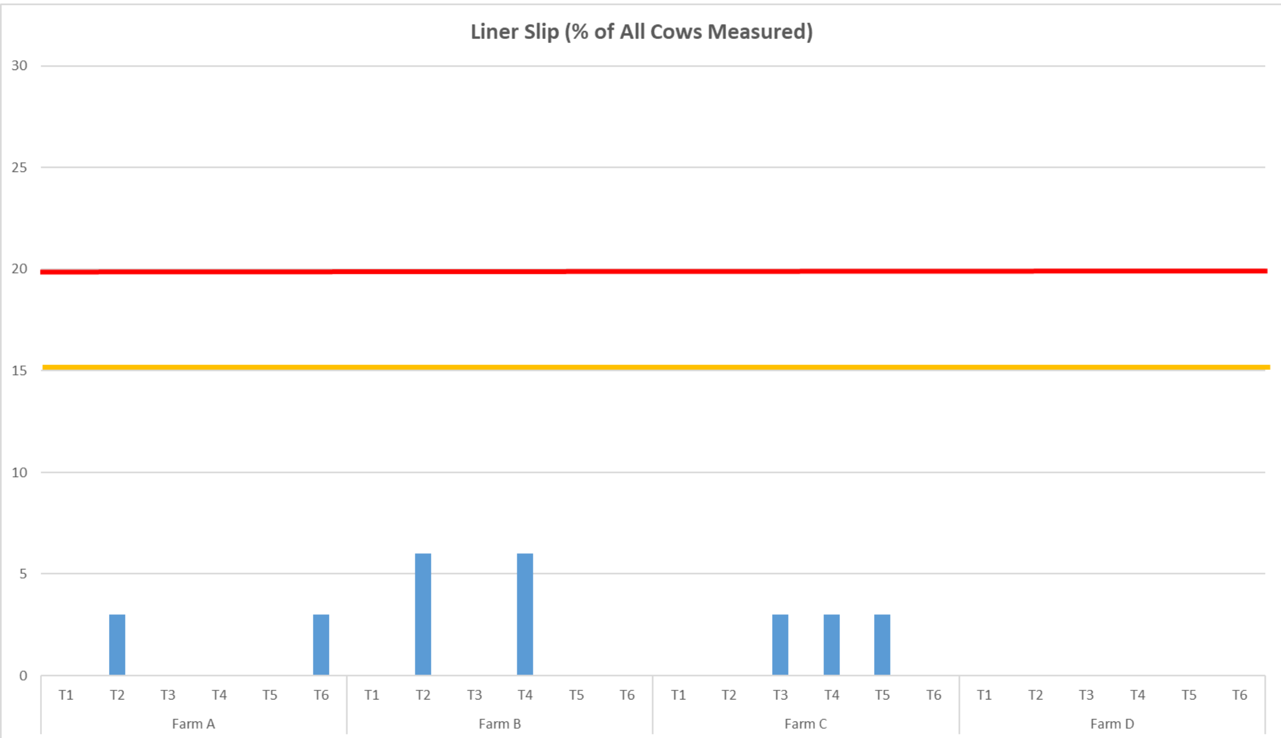
Figure 10. Incidence of poor liner fit



Liner Slip

The following graph shows the incidence of liner slip during each dynamic testing, expressed as a percentage of all cows tested during that visit. The amber coloured line represents the monitoring level, whereas the red line indicates the intervention level (Figure 11):

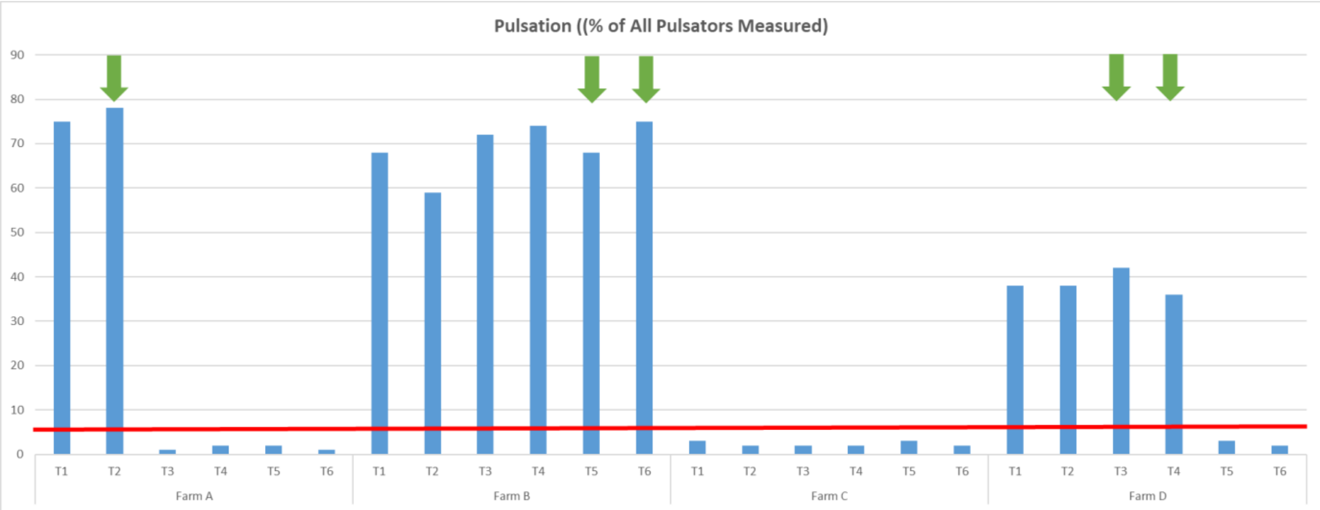
Figure 11. Incidence of liner slip



Milk Plant Pulsation

The following graph shows the incidence of pulsation issues during each dynamic testing, expressed as a percentage of all pulsators tested during that visit. The red coloured line indicates the intervention level. The green arrows indicate the time period where intervention took place. In this case, intervention addressed issues with any of the pulsation areas of interest (Figure 12):

Figure 12. Incidence of pulsation issues



Teat Measuring

The following tables outline the teat scoring findings on each participating farm (Table 8a):

Table 8a. Teat scoring findings

	Farm A											
	T1		**T2**		**T3**		**T4**		**T5**		**T6**	
	Length (mm)	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**
Arithmetic Mean	48.33	26	47.54	26	43.20	25.95	41.04	24.00	40.63	24.06	43.92	22.38
Standard Deviation	8.84	4.02	8.52	3.78	7.29	5.58	7.39	4.54	7.10	4.75	6.75	4.72
Median	48	26	48	26	42	26	42	24	40	24	43	20
	Farm B											
	T1		**T2**		**T3**		**T4**		**T5**		**T6**	
	Length (mm)	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**
Arithmetic Mean	38.91	21.12	38.21	20.88	37.67	20.00	36.93	20.67	40.67	20.33	34.00	20.94

Standard Deviation	7.31	3.77	6.91	3.24	6.26	2.99	9.04	3.27	4.28	3.16	5.70	4.75
Median	40	20	40	20	38	19	38	20	40	20	32	22
	Farm C											
	T1		**T2**		**T3**		**T4**		**T5**		**T6**	
	Length (mm)	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**
Arithmetic Mean	42.11	24.08	41.56	23.22	44.19	22.67	39.72	21.44	38.17	21.53	40.57	21.59
Standard Deviation	7.12	4.05	6.48	3.70	8.09	3.84	5.84	4.03	5.54	3.82	7.31	4.53
Median	42	22	42	22	44	22	40	22	40	20	40	20
	Farm D											
	T1		**T2**		**T3**		**T4**		**T5**		**T6**	
	Length (mm)	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**
Arithmetic Mean	41.21	25.12	40.78	24.85	42.10	24	41.89	23.70	38.35	22.55	37.21	21.98
Standard Deviation	7.83	4.61	7.09	4.04	6.78	4.97	7.02	4.23	4.96	3.48	6.84	3.87
Median	42	24	42	24	42	23	42	24	38	24	40	24

The summarised results for each participant are as follows (Table 8b):

Table 8b. Summary of results for each farm

		Farm A	**Farm B**	**Farm C**	**Farm D**
Arithmetic Mean	**Length (mm)**	44.11	37.73	41.05	40.26
	Width (mm)	24.73	20.66	22.42	23.70
Standard Deviation	**Length (mm)**	7.65	6.58	6.73	6.75
	Width (mm)	4.57	3.53	4.00	4.20
Median	**Length (mm)**	43.83	38.00	41.33	41.00
	Width (mm)	24.33	20.17	21.33	23.83

Bacteriology & Sensitivity

Although the initial intention was to submit as many sterile milk samples as possible from clinical mastitis cases, in practice this part of the project produced varied results with some participants submitting more diligently than others. For these reasons, it was decided that we would not comment on this variable. Furthermore, the lead vet selected from the farm's milk recording data a number of cows with subclinical mastitis to have a sterile milk sample collected. The numbers of milk samples submitted and associated pathogens are shown on the following table. A number of cultures had mixed findings (Table 9):

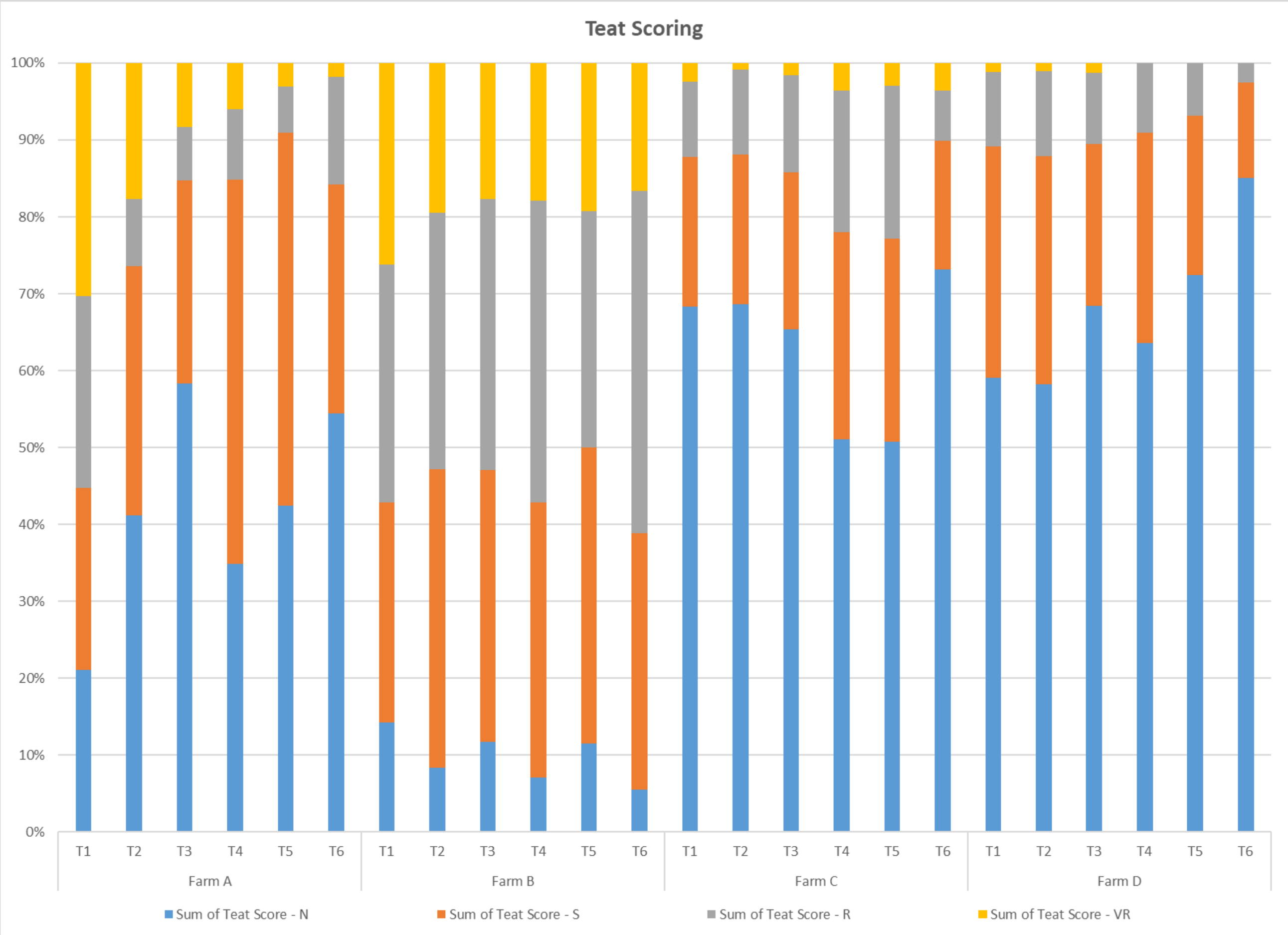
Table 9. Pathogens detected in milk samples

	Farm A					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Total Samples	11	13	26	31	22	18
NSF	4	2	8	9	5	3
Coliforms	3	4	9	8	14	10
Strep uberis	3	2	3	5	2	1
Coag. +ve Staphs	1	3	6	6	2	3
Staph aureus	2	3	4	5	3	3
	Farm B					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Total Samples	14	16	26	28	21	14
NSF	3	2	4	2	6	5
Coliforms	6	10	12	14	9	3
Strep uberis	3	5	10	8	4	4
Coag. +ve Staphs	4	3	4	6	4	3
Staph aureus	0	0	0	1	0	0
	Farm C					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Total Samples	12	22	29	24	20	17
NSF	3	5	7	2	3	1
Coliforms	8	14	16	20	16	13
Strep uberis	2	2	3	1	2	1
Coag. +ve Staphs	1	2	4	3	2	2
Staph aureus	0	1	0	0	0	0
	Farm D					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Total Samples	10	18	24	26	24	12
NSF	3	1	5	5	3	2
Coliforms	6	17	16	19	21	6
Strep uberis	1	0	3	0	0	2
Coag. +ve Staphs	1	0	2	2	0	3
Staph aureus	0	0	0	0	0	0

Teat Scoring

The following graph shows the findings of teat scoring during each dynamic testing, expressed as a percentage (Figure 13):

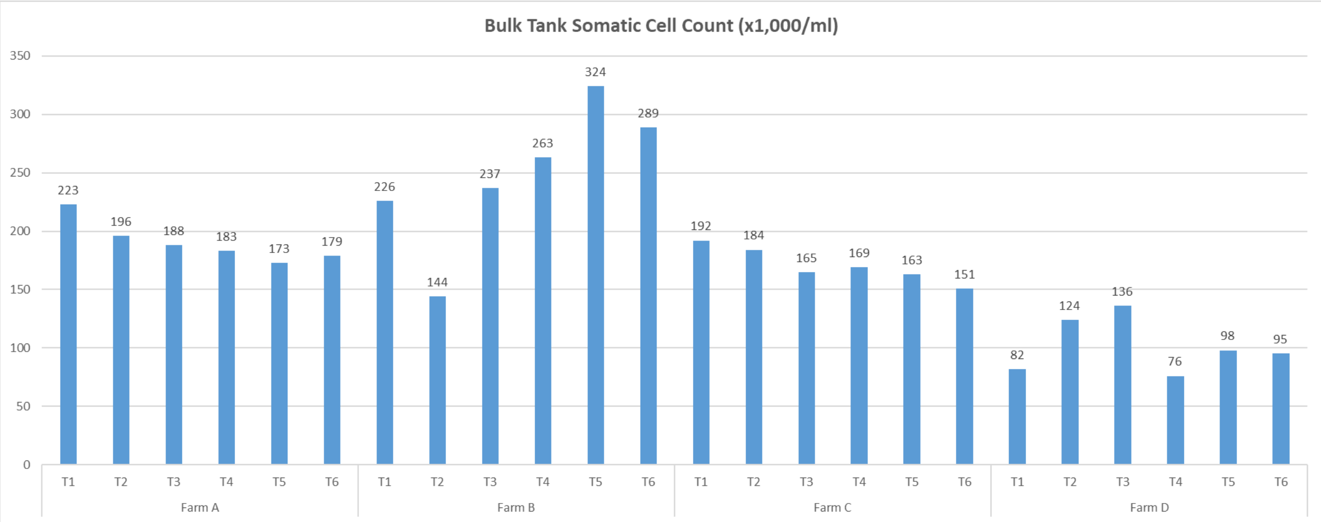
Figure 13. Teat scoring



Bulk Tank Somatic Cell Counts

The following graph shows the BTSCC results, expressed as thousands of somatic cells per millilitre (Figure 14):

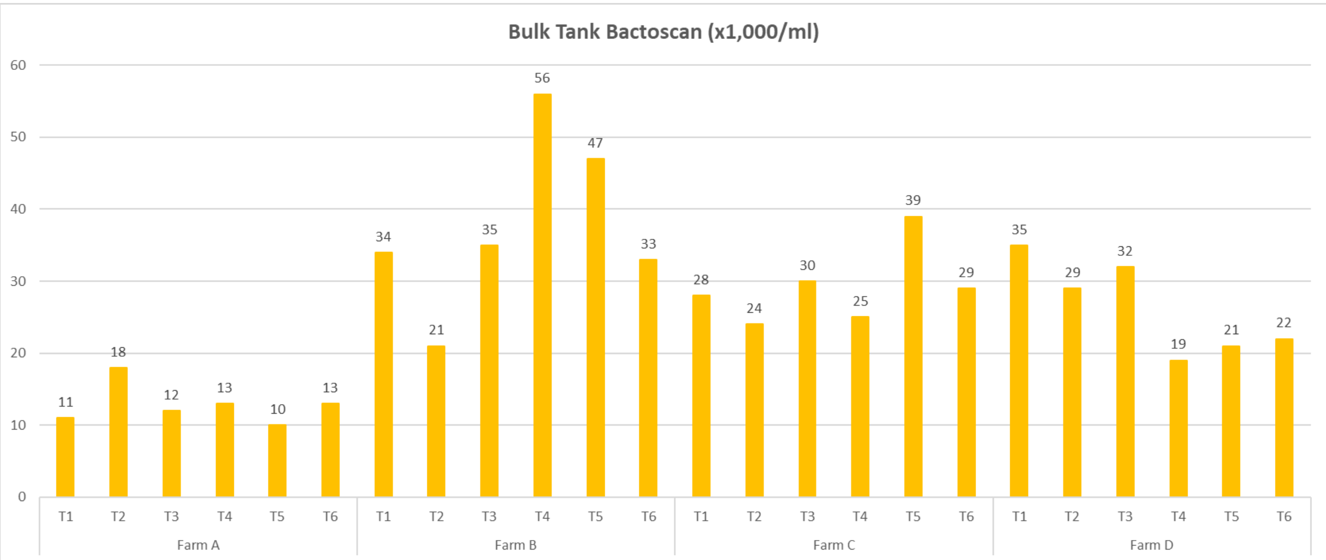
Figure 14. Bulk tank somatic cell counts



Bulk Tank Bactoscan

The following graph shows the BACTO resuFlts, expressed as thousands of bacteria per millilitre (Figure 15):

Figure 15. Bulk tank Bactoscan results



Clinical Mastitis Incidence (Quarter)

Recording of mastitis cases per cow or per affected quarter by the participants fell below expectations throughout the project. In some herds, only cases of mastitis that required treatment were recorded in the medicine book, but further information such as the affected quarter were missing.

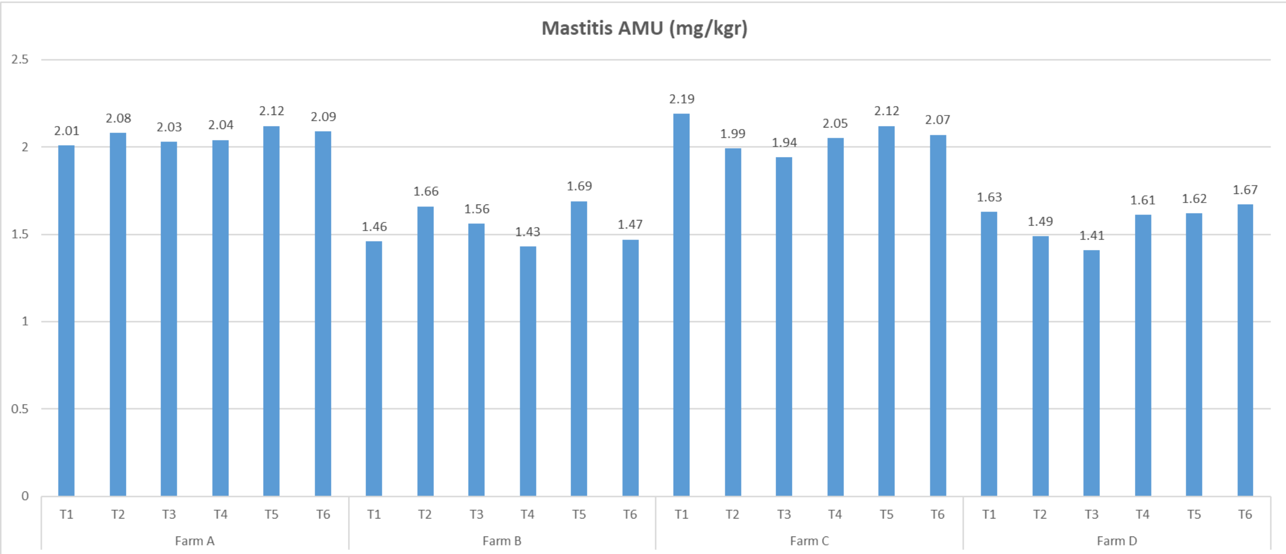
With the exception of one participating herd clinical mastitis incidence was substantially underestimated, in the region of between 15% and 80%. For these reasons, it was decided that we would not comment on this variable.

Mastitis Antibiotic Treatment Use

The AMU for mastitis treatments of the participating herds was calculated, while bearing in mind that some were using injectable antimicrobial preparations instead of intramammary ones as part of their standard mastitis treatment protocol.

The following graph shows the AMU for mastitis treatments, expressed as milligrams of antimicrobial used per kilogram of standard body liveweight (Figure 16):

Figure 16. Antimicrobial usage (AMU) for mastitis across the four farms



The statistical analysis for all three outcome variable groups is shown below. The computations are based on individual cow-level observations of each of the outcome variables of the dynamic testing group and the secondary outcome group, as well as herd-level observations of the primary outcome group. Values are frequency N (%), coefficient of linear regression, 95% confidence interval, P-value and its interpretation. The analysis is multi-level (adjusted) mixed effects regression with farm as random effect on 666 cows for the dynamic testing group and a further 162 cows for the pulsation testing, 1,731 cows for teat scoring and 456 milk bulk tank measurements (Table 10):

Table 10. Statistical analysis for the outcome variable groups

	Frequency N= (%)	Coef Linear Regress (95% Conf Interval)	P – value	Interpretation
Biphasic Milk Flow	38 (5.70)	No relevant intervention packages were applied		
Strong Outcome Predictors	*Not applicable*			
Overmilking	421 (63.21)	-0.21 (-0.34 - -0.11)	0.006	Strong Evidence
Strong Outcome Predictors	*Time period (T1 to T6), Nature of the Visit (Control or Intervention)*			
Poor Flow Away from The Cow	76 (11.41)	-0.42 (-0.78 - -0.04)	0.036	Some Evidence
Strong Outcome Predictors	*Time period (T1 to T6), Nature of the Visit (Control or Intervention)*			
Poor Liner Fit	375 (56.30)	-0.07 (-0.24 - +0.09)	0.081	Insufficient Evidence
Strong Outcome Predictors	*None*			
Liner Slip	7 (1.05)	No relevant intervention packages were applied		
Strong Outcome Predictors	*Not applicable*			
Milk Plant Pulsation	161 (24.17)	-0.48 (-0.73 - -0.28)	0.002	Strong Evidence
Strong Outcome Predictors	*Time period (T1 to T6), Nature of the Visit (Control or Intervention)*			
Teat Scoring	364 (21.03)	-0.12 (-0.25 - -0.04)	0.028	Some Evidence
Strong Outcome Predictors	*Time period (T1 to T6), Nature of the Visit (Control or Intervention)*			
Bulk Tank Somatic Cell Counts	118 (25.87)	-3.86 (-5.78 - -1.91)	0.008	Strong Evidence
Strong Outcome Predictors	*Time period (T1 to T6), Nature of the Visit (Control or Intervention)*			
Bulk Tank Bactoscan	19 (4.16)	-6.12 (-21.87 - +12.34)	0.059	Insufficient Evidence
Strong Outcome Predictors	*None*			
Mastitis AMU	N/A	-0.03 (-0.81 - +1.09)	0.068	Insufficient Evidence
Strong Outcome Predictors	*None*			

8. Discussion

This project was designed to investigate the impact on udder health in dairy herds through a series of intervention packages, while using dynamic milk parlour testing as one of the decision-making tools. This is a complex project, due to the numerous levels that were monitored. As the number of participants and enrolled cows is relatively small, this project amongst other things should serve as a hypothesis generating study. We are hoping that this project will hopefully give rise to other similar but larger scale research trials.

It is also important to bear in mind that the aim of the project was not to ascertain on whether specific interventions have an impact on herd udder health. Each package of interventions was relevant to the monitoring of each herd's performance, as well as what was practical to be applied in each herd. Finally, it is worth reiterating that monitoring took place on cow-level, whereas the aforementioned packages of interventions and this project's reporting were applied on herd-level.

Of the original set of outcomes, we decided not to include in the final model a number of them. Biphasic milk flow and liner slip of the dynamic testing group of outcomes did not appear to be an issue on any of the participants throughout the project. This is a fantastic finding, indicating efficient control of these areas from the participants. On the other hand, this does not mean that biphasic milk flow and liner slip are not a contributing factor to udder health on other dairies in Wales and the rest of the UK. A wider study is required to understand the extent, if any, of those two variables.

Furthermore, it was decided not to include Clinical Mastitis Incidence into the model. It appears that participants were recording mastitis, but were significantly biased toward recording clinical cases that required antimicrobial treatment. Animals affected by mild clinical cases of mastitis caused by bacteria such as coliforms, may very often undergo self-cure and therefore not require antibiotic treatment. As such mild clinical cases may not be recorded, we were concerned that including this outcome variable in the model would possibly have undermined other outcomes of this project.

This project found strong evidence (P-value 0.006) that for every package of interventions applied in the herd, the incidence of overmilking in the herd reduced by 21%, adjusting for time period and nature of the visit (Stata, 95% CI -34% to -11%). Overmilking is one of the primary mechanisms of damage to the teat end, which in turn is one of the many defence barriers of the udder to mammary infection. It is a common misconception amongst some producers, that automation comes with more efficiency. This project identified that a number of ACR were not functioning properly and resulting in overmilking of the quarter. In the author's opinion, the primary contributor in the mal-function of the ACR is the lack of testing in those devices. The static test that each milking parlour has to undergo at least once a year does not include a health check of ACR function. Therefore, should ACR testing become obligatory, ACR malfunction should be identified more regularly and such improvement in ACR performance should translate in better udder health.

This study identified some evidence (P-value 0.036) that for every package of intervention applied in the herd, the incidence of poor milk flow away from the teat reduced by 42%, adjusting for time period and nature of the visit (Stata, 95% CI -78% to -4%). This finding was relevant to one of the participants only, who years after the installation of the milking plant, installed a backflush unit. Such units are becoming popular and they are aimed to clean with hot water and disinfectant the milk unit after it has been removed from a cow and before it is applied to the next. It is believed that such a cleansing process will reduce the number of bacteria present in the interior of the liner and therefore reduce the likelihood of infection to the next cow. Although this particular model of backflush unit was recommended by the parlour installer, it was not produced by the manufacturer of that particular milking plant. The issue of poor milk flow away from the teat became more evident during times of higher milk yields per cow. As larger volumes of milk were drawn away from the cows, the milk plant had to force the passage of increased volume through the backflush unit that had nearly half the inner diameter compared to the adjacent long milk tube before and after its point of installation. Such constrictions in the milk lines interrupt the flow of milk and change its pattern from streamline to whirls. These interruptions of the milk flow may increase the risk of milk becoming stationary while forming whirls and eddies, particularly around the teat-end. There is concern that such swirling motion of milk around the teat-end, which in turn is regularly forced to open up during the milk out phase, may lead to reverse flow of milk back into the teat cistern and the mammary quarter and with it carry harmful mastitis pathogens.

This research ascertained insufficient evidence (P-value 0.081) that for every package of interventions applied in the herd, the incidence of poor liner fit was not in any way affected, adjusting for time period and nature of the visit (Stata, 95% CI -24% to +9%). There are a number of reasons for this finding. The average teat size varied within each herd and between participants. For example, Farm A had on average longer and wider teats compared to any of the other participants. More importantly the teat size varied between cows of the same herd, with the lowest standard deviation for teat width was found to be 3.53 millimetres in Farm B and the highest standard deviation for teat width was found to be 5.47 millimetres in Farm A. This creates an important consideration when deciding which liner fit is the most appropriate to change to. The new liner fit has to accommodate at least 80% of the milking cows in the herd. Diverse herds, as the participating ones, were not always available to achieve the 80% target compliance. Furthermore, manufactured teat liners have to comply with farm assurance and milk buyer standards, which a number of products in the market do not. Additionally, teat liner manufacturers do not produce a vast number of liner sizes, but instead do a limited number. Finally, changing teat liner size, in order to improve liner fit, comes with altering the hard shell that surrounds them and this may be a major investment.

Improving liner fit comes with better contact of the teat in the mouthpiece chamber of the liner and reduces air leakage into the milk plant. Once the milk units are attached to the udder and the process of milking commences, the skin of the teat swells slightly. In a milk liner that fits perfectly, this comfortable fit between the teat and the liner seals any gaps on the milk liner and reduces uncontrolled leakage of air into the milk plant. On the other hand, in cases of poor liner fit, this is accompanied by increased leakage of air into the milking machine and disruptions of the milk flow. In the author's opinion, the packages of interventions failed to produce sufficient evidence that they in any way affect the incidence of poor liner fit, because most participants elected not to address this issue. Remedying a high incidence of liner fit comes with higher costs, while it was not clear how much improvement such remedy will bring in improving udder health. Wider scale practical studies are required in quantifying the impact on udder health of any improvements on poor liner fit.

This project found strong evidence (P-value 0.002) that for every package of interventions applied in the herd, the incidence of inadequate milk plant pulsation reduced by 48%, adjusting for time period and nature of the visit (Stata, 95% CI -73% to -28%). Pulsation of the milk plant includes many aspects of milk machine performance and although this study was not designed to examine every attribute in detail, there were a number of interventions available. In reality, the packages of interventions applied most often were associated with individual pulsator function and long pulsation tube cleanliness. Over time, both pulsators and pulsation tubes become contaminated with dust and slime, hence reducing their effectiveness in transporting vacuum in the various parts of the milk plant. It is the finding of this project, that once the pulsators and pulsation pipes were cleaned or replaced, the subsequent improvements in those parts were quite evident at the next dynamic test. This should also raise an important point about when these parts of the milk machine be regularly checked, in order to detect early any deterioration of their performance. The obligatory annual static test of the milk plant is the obvious area that may be proposed here, but in the author's experience these checks are not always carried out.

This study identified some evidence (P-value 0.028) that for every package of interventions applied in the herd, the average incidence of combined rough and very rough rings found during teat scoring of the teat-end was reduced by 12%, adjusting for time period and nature of the visit (Stata, 95% CI -25% to -4%). It is the hypothesis of this project that improvements in udder health will be the outcome of implementing packages of interventions emanating from the findings of each dynamic testing, which in turn will lead to improved teat scoring. This study has already uncovered strong evidence in the reduction of Overmilking, some evidence in the reduction of Poor Flow Away from The Cow and strong evidence in the reduction of inadequate Milk Plant Pulsation. The author believes, that all three of these factors result in diminished exposure of each teat to unnecessary and prolonged vacuum levels at the teat-end, particularly at times of low milk-flow. Eventually, a sound teat-end is a more effective defence asset to preventing clinical and subclinical mastitis.

This research ascertained strong evidence (P-value 0.008) that for every package of interventions applied in the herd, the average bulk tank somatic cell counts reduced by 3.86 x1,000/ml, adjusting for time period and nature of the visit (Stata, 95% CI -5.78 x1,000/ml to -1.91 x1,000/ml). Although investigating every area that contributes to improvements in bulk tank somatic cell counts was outside the remit of this limited project, the strong evidence found here are consistent with this study's hypothesis. In particular, that improvements in BTSCC will stem from improving teat score results, which will follow the progress in the dynamic testing findings.

This project found insufficient evidence (P-value 0.059) that for every package of interventions applied in the herd, the average BACTO was not in any way affected, adjusting for time period and nature of the visit (Stata, 95% CI -21.87 x1,000/ml to +12.34 x1,000/ml). While investigating every area that contributes to improvements in bulk tank bactoscan was also outside the remit of this limited project, the overall performance of this outcome in each participant was satisfactory, with only 4.16% of all bulk tank bactoscan readings warranting intervention. Therefore, most of the packages of intervention applied were not aimed at improving BACTO. A wider study is required in order to draw clearer conclusions in this region.

This study identified insufficient evidence (P-value 0.068) that for every package of interventions applied in the herd, the average mastitis AMU was not in any way affected, adjusting for time period and nature of the visit (Stata, 95% CI -0.81 mg/kg to +1.09 mg/kg). Although examining in detail the associations between relevant variables and the reduction in use of antimicrobial preparations for the treatment of mastitis was not within the scope of this assignment, the overall AMU in each participating herd was well within acceptable levels. Additionally, a number of cases of clinical mastitis were not treated with antimicrobials as a matter of routine in some participating herds. Particularly cases with milk clots, but without any other accompanying symptoms such as mammary inflammation or generalised symptoms, were treated with supportive therapy only and the milk from these cases was discarded. Identifying the exact impact of our package of interventions on AMU requires a more detailed study, with a significantly larger sample population.

9. Conclusions

This project worked with four diverse dairy farming systems and concluded that milk parlour dynamic testing leads to change in the milking machine and in the milking routine, which in turn results to positive change around udder health performance. The effects are multi-faceted, the vets benefit, the cows benefit, so does the farming enterprise.

10. Conflict of Interest

The author offers independent milk parlour dynamic testing service to dairy clients, focusing on udder health and improving the quality of milk.

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