Department of Animal Hygiene, Herd Health and Mobile Clinic

University of Veterinary Medicine

The use of selective antibiotic dry cow therapy in Ireland, its role in reducing antimicrobial usage and its effect on animal health, milk quality and its economic effect

By

Cliodhna O’Sullivan

Supervisor

Dr. Péter Kovács

Budapest, Hungary

2020

Table of Contents

1. Introduction

1.1. The need for Selective dry cow therapy to reduce AMR

For years, blanket antibiotic dry cow therapy (BDCT) was the only method used, not only in Ireland but, on dairy farms worldwide. Antibiotic dry cow therapy is carried out at the beginning of the dry period to allow time for cows' body and mammary tissue to repair itself after the lactation. Blanket antibiotic dry cow therapy means that's every cow will receive an intramammary antibiotic in each quarter. Historically, the aim of this was to treat any existing intramammary infections and prevent any new infections that may occur. In response to the ever-rising battle against Antimicrobial Resistance (AMR), as of January 2022 under Regulation (EU) 2019/6 on veterinary medicinal products, this metaphylactic and prophylactic antibiotic usage is no longer allowed.

Selective dry cow therapy (SDCT) is a strategy where cows are selected based on certain criteria such as cow and herd somatic cell count (SCC) and the occurrence of cases of clinical mastitis with each individual. A decision is then made based on this information whether the cow will be given an intramammary dry cow antibiotic and a teat sealant or a teat sealant alone or neither. The main purpose of SDCT is to reduce the unnecessary use of antibiotics at drying off. However, it is important to note that the farms clinical and subclinical mastitis cases should be under control before implementing SDCT on the farm.

By 2050, it is estimated that AMR-related deaths in humans will have increased more than 10-fold globally, with more people dying of AMR than from cancer. AMR is responsible for an estimated 25,000 deaths and €1.5 billion in extra healthcare costs every year in the EU alone. Hence the sense of urgency about addressing this issue, and doing so at a global level. (IACG, 2019)

1.1.1. <u>SDCT: Key technical aspects</u>

Mastitis is the inflammation of the mammary gland which can present itself in a clinical or subclinical form. Pathogens usually enter through the open teat canal either from the environment or at milking and gradually migrate upwards into the gland tissue of the udder. With clinical mastitis **(CM)**, changes will be seen both in the milk and anatomy of the udder. With subclinical mastitis **(SCM)** cases, these changes are more subtle. Cases may often only be recognised through an increase in white cells i.e. an increase in the somatic cell count. The cow's production and milk quality may also be negatively affected. Both clinical and subclinical cases of mastitis can act as a source of infection for other cows within the herd. These pathogens are normally either contagious pathogens such as e.g. *Staph. aureus* or more environmental type pathogens e.g. *E. coli.*

As part of my research, I utilised information collected by Animal Health Ireland (AHI) through "CellCheck" of farms within County Meath, Ireland. Using the information regarding the monthly bulk tank SCC, I examined the progress made since the implementation of SDCT, the percentage within the herd whose SCC >200,000cells/ml and look at the individual cows who are causing these increases in the bulk tank SCC. With individual cows, I then examined new infection rates and persistent infection rates that occurred. This allowed the problem to be pinpointed to either a select few problem cows, or if the higher SCC is a generalised problem. Finally, and most importantly for the farmer, I examined the economic impacts of implementing SDCT on the individual farms.

2. Literature review

With DCT, our main goal is to eliminate existing intramammary infections and to prevent new infections occurring during the dry period. There are some important points to consider before diving into the implementation of SDCT on farm. Herd suitability is highly important. SDCT is more safely approached if the herds bulk tank SCC is <200,000cells/ml over a 3 month period before drying off, if the clinical mastitis case rate is <2% in the previous 3 months of lactation, if the farmer is recording cases of clinical mastitis and their outcomes, if milk culture results are being examined, if the recent infection rate of the herd is 5% consistently and if milk recording is being carried out on a monthly basis, as well as excellence at drying off.

Within these suitable herds, individual cows will be examined to see if they are suitable to receive SDCT. These cows shall receive no intramammary antibiotic therefore it is vital that we ensure they are suitable. In Ireland, it is recommended that these cows must have a SCC of <100,000cells/ml and must have had no cases of clinical mastitis in the previous lactation period. These cows should also have a California Milk test carried out before the drying off process ("CellCheck" Ireland, 2019). It is of the utmost importance that these criteria are adhered to when performing SDCT. If not, this can lead to detrimental effects on the overall udder health of the cattle, it may lead to an excessive use of antibiotics in order to treat certain cases of mastitis and most importantly it can result in huge economic losses for the farmer in terms of veterinary fees, antibiotics, early culling of cows and loss of milk earnings.

2.1. Selective Dry cow therapy: Implementation, efficacy and economic impacts

In 2014 (Scherpenzeel et al., 2014), a study was carried out to evaluate the outcome of SDCT on herds with a low SCC at their last milk recording prior to drying off. Thresholds were set depending on the parity of the cows being investigated. From these herds, low SCC was defined as <150,000 cells/ml for primiparous cows and <250,000 cells/ml for multiparous cows. A total of 1,657 cows from 97 herds had data collected from them and analysed. A split-udder design was used meaning that 2 of the 4 quarters received antimicrobial treatment at drying off and the other 2 quarters remained untreated. This allows the elimination of a control group and also helps eliminates variables such as genetics, feed rations, the use of the same milking machinery, that may affect the results. However, the possible downfall of this method is that the quarters that are dried off with antibiotics may affect those that are not. Milk samples were taken from each quarter at drying off, within 12 hours of calving and finally at 14 days in milk **(DIM)**. Cows were only considered suitable for this study provided they has no significant teat lesions; they were in good health at drying off and they had four functional quarters. All of these animals were followed from drying off until 100 days into lactation period. In terms of antibiotic use, it was calculated for this study as 1 animal daily dosage **(ADD)** per quarter treated at drying off. In 89% of the herds examined, one or more cases of CM were recorded between drying off to 100 days in milk. 319 cases of CM in 243 cows were documented. 182 cows out of 243 had 1 quarter affected, 50 cows had 2 quarters affected, 7 cows had 3 quarters affected and 4 cows had all 4 quarters affected. 200 of these cases occurred within cows that had been dried off without intramammary antibiotics and the remaining 119 occurring in cows that had been dried off with antibiotics. Repeat cases of CM were not included in the results for analysis. When SCC was examined, quarters with a higher SCC at drying off were at risk of having an SCC >200,000 cells/ml at 14 days in milk. Quarters that were found to be positive for major pathogens at drying off were also found to be at greater risk of having an SCC >200,00 cells/ml at 14 days in milk. When antibiotic use was inspected, quarters dried off with antibiotics showed a total of 3,692 ADD having been used including CM treatments. For those cows that received no antibiotic DCT, a total of 541.5 ADD used. During this study, it was noted that the incidence rate of CM was highest during the dry period and the first 21 days of lactation. Up to 50% of enterobacterial CM cases that occurred with the first 100 days in milk were occurring in quarters that were already infected during the dry period. SCC at both cow- and quarter-level recorded within 12 hours of calving and 14 days in milk showed to be significantly higher in quarters that were dried off without the use of antimicrobials. Despite the increased use of antibiotics for the treatment of cases of CM, there was a notable reduction in the use of antibiotics related to mastitis. 85% less antibiotics based of the calculation of the ADD on quarter level in quarters dried off without antibiotics. In their conclusion, they outlined that although SDCT may lead to more cases of CM and cows that had originally recorded low SCC becoming high SCC cows, the reduction in the use of antibiotics is convincing. (Scherpenzeel et al, 2014)

In a study carried out by (Scherpenzeel et al., 2016) they selected animals for DCT using different SCC at cow-level and also with varying parities. Their aim was to examine the outcome of udder health of the cows by the end of the study, the overall antimicrobial usage and most importantly, the economic impact when using these selection permutations. They carried out 8 different scenarios, 7 of which utilised SDCT based on SCC. Three different scenarios used SCC of 50,000 cells/ml, 100,000 cells/ml and 150,000 cells/ml (Scenario 2,3 and 4 respectively). There was no differentiation between parity of cows with these scenarios. For the remaining four scenarios, there were different thresholds used for primiparous cows and multiparous cows (150,000 for primiparous and 50,000 cells/ml for multiparous, 150,000/100,000 cells/ml, 150,000/200,000 cells/ml and 150,000/250,000 cells/ml), scenario 5, 6, 7 and 8 respectively. They created a virtual herd of 100 cows to carry out analysis on the basis of the 8 different scenarios. 97 herds were used in the field trial. For each scenario, the virtual herd was divided into 7 groups based off of SCC at drying off and parity. Depending in the scenario SCC threshold level, cows were selected for SDCT. Within each scenario, clinical mastitis, number of quarters with an SCC >200,000 cells/ml at 14 DIM, antimicrobial usage and economics were analysed. With clinical mastitis cases, there were 319 quarter cases in 243 cows recorded from the dry period to 100 DIM. It is important to note that repeat cases of clinical mastitis were not recorded. They found that incidence rate of CM at cow-level was higher in multiparous cows, especially those who had no DCT, only a teat sealant. Of the field trial herds, 1,003 cases of SCM were seen at 14 DIM and on average 1.5 quarters with a high SCC per cow. Scenario 8 was found to have the highest SCM at 48.3%. Antimicrobial usage was expressed for each scenario for DCT and CM treatments as the number of ADD. One ADD was outlined as a standardised treatment for a period of one day. For DCT, one quarter was treated with one ADD. The average ADD per case of CM was then used to calculate and approximate the antimicrobial usage. The study found that 3 ADD was the average antimicrobial usage per case of CM. Amongst the different scenarios, the differences in antimicrobial usage was significant. For scenario 1, on average 2.68 ADD was being used as opposed to scenario 8 where .68 ADD was being used. The total antimicrobial usage for both DCT and CM treatment ranged from 1.27 ADD in scenario 8 to 3.15 ADD in scenario 1. This showed that scenario 8 had a 60% reduction in antimicrobial usage. Finally, economic analysis showed that the cost of DCT ranged from €972 for BDCT to €247 for scenario 8. The cost of CM varied from €3,470 for BDCT to €4,354 for scenario 8 and the cost of SCM varied from €628 for BDCT to €782 for scenario 8. It is quite evident form this study that the outcome of the SDCT scenarios heavily depended on the cows selected and their SCC threshold.

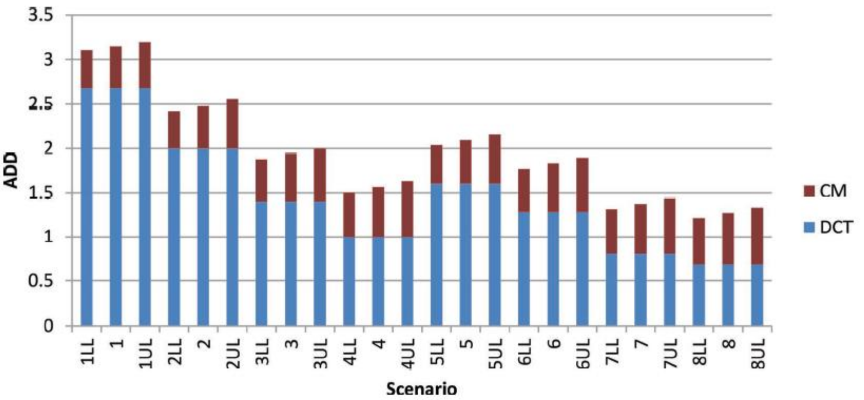


Diagram 1 shows the ADD of all the scenarios. (Scherpenzeel et al., 2016)

Note, scenario 1 is the BDCT method which shows it using between 3-3.25 ADD per quarter. In comparison to scenario 8 where there was a larger SCC range used for the selection of cows (150,000 cells/ml for first parity cows and 250,000 cells/ml for multiparous cows), there was between 1-1.5 ADD used per quarter. When examining the financial implications of the study, it showed that the total cost, if done correctly, SDCT can be more cost-friendly than BDCT. Scenario 1 (BDCT) resulted in a total cost of €5,070 in comparison to scenario 2 (SCC <50,000 cells/ml for primi- and multiparous) which ended with a total of €4,946 and scenario 5 (SCC <150,000 cells/ml for primiparous and <50,000 cells/ml for multiparous cows) which resulted in a total cost of €4,893. Although the cost difference is not significant, long term it would make a difference to the farmers finances. This study estimated that each case of CM cost around €221 to treat an average the calculated from (Huijps et al., 2008). For SCM, losses were calculated by using losses through milk production multiplied by the cost per kilogram of milk. The average milk production loss per cow >200,000 cells/ml was 0.81kg/day. Using this, they calculated the economic losses of a case of SCM as €16.20. As well as this, the cost for DCT was set at €14.50. By not strictly adhering to selection criteria for SDCT, the outcome can be financially detrimental to the farmer. (Scherpenzeel et al., 2016)

In 2018, (Scherpenzeel et al., 2018) conducted a study to focus on the economic optimization of SDCT. The aim was to identify the percentage of cows that could be dried off with antimicrobials that would result in the lowest cost. They utilised a mathematical linear programming model to do so which represented the total economic cost of mastitis as the sum of both the preventative costs and costs that are then required to treat cases of mastitis in case of failure and the losses that ensued. Three different types of herds were used based on their bulk tank SCC (low <150,000 cells/ml, average >150,000 cells/ml and <250,000 cells/ml and high, >250,000 cells/ml and <400,000 cells/ml). They were then divided in categories based on parity and SCC from the last milk recording. The percentage of cows dried off using antimicrobials ranged between 0-100% in order to show correlation between the maximum percentage of cows dried off with antimicrobials and the resulting economic consequences. A crucial point made was that to achieve the optimal percentage of cows dried off with antimicrobials, it is heavily dependent on the udder health situation, this would be evaluated through the bulk tank SCC and the incidence rate of CM on the farm. Nine groups were formed, four of which were for those undergoing their first dry period (Group 1, 0-50,000cells/ml; Group 2, 51,000- 100,000cells/ml; Group 3, 101,000-150,000 cells/ml and Group 4, >151,000 cells/ml). Five groups were formed for multiparous cows (Group 5, 0-50,000 cells/ml; Group 6 51,000-100,000 cells/ml; Group 7 101,000-150,000 cells/ml; Group 8 151,000-250,000 cells/ml and Group 9 >250,000 cells/ml). In terms of antimicrobial usage, the average number of days a cow would receive antimicrobial treatment or animal defined daily dosage **(ADDD)** was calculated as 4.0 ADDD for drying off and for a case of CM treatment, 3.0 ADDD. In this study, the cost of a case of CM in the first 100 DIM was set at €242. This was calculated based on the method used by (Huijps et al., 2008). Simulations were run with the number of cows requiring antimicrobial treatment at drying off, with each simulation being reduced each time by 5%. The cost associated with drying off per cow varied depending on the herds bulk tank SCC. In the low bulk tank SCC herds, it cost €45 per cow to be dried off, if 100% of cows were being given antimicrobials. In the high bulk tank SCC herd, it cost €56 per cow if no antimicrobials were being used. CM and SCM cases ranged from 9.9-16.1% and 8.2-19.6%, respectively. In relation to antimicrobial usage, this varied from 0.6 ADDD, when no antimicrobial was allowed to be used at dry off, to 3.9 ADDD when 100% of cows received antimicrobials at drying off.

Herd type	BDCT	100% dry cow antimicrobials allowed	Difference 100% − BDCT	0% dry cow antimicrobials allowed	Difference 0% − BDCT
BT_HC_H	6,512	6,464	−48	8,085	1,573
BT_AC_H	6,152	6,049	−103	7,601	1,449
BT_LC_H	5,828	5,705	−123	7,155	1,327
BT_HC_A	3,928	3,838	−90	4,202	274
BT_AC_A	3,741	3,557	−184	3,943	202
BT_LC_A	3,554	3,339	−215	3,685	131
BT_HC_L	2,636	2,260	−376	2,260	−376
BT_AC_L	2,538	2,114	−424	2,114	−424
BT_LC_L	2,417	1,949	−468	1,949	−468

[1]Calculations were done for a high-bulk tank SCC (BTSCC) herd (BT_H), an average-BTSCC herd (BT_A), and a low-BTSCC herd (BT_L), each with a low (C_L), an average (C_A), and a high (C_H) incidence of clinical mastitis and the difference between 100% and BDCT and between 0% and BDCT.

Table 1. Economic costs of mastitis in BDCT herds and minimised total economic costs of mastitis with 100-0% dry cow antimicrobials used. (Scherpenzeel et al., 2018)

Table 1 shows that even if there is a high bulk tank SCC on farm combined with a low incidence rate of CM, it is far more detrimental to the economy of the farm if there were higher incidences of CM combined with a low bulk tank SCC. It also shows that BDCT will always be more costly than SDCT. Even if BDCT is implemented on a farm with a low incidence of CM, it will still be more expensive than of there were 0% of antimicrobials used on farm at drying off. The results of this study found that herds with a high bulk tank SCC and high incidence of CM, 80% of cows would have to be dried off with antimicrobials in order for the farm to minimise its costs with antimicrobial use. For the herd with an average bulk tank SCC and high incidence of CM, this was set at 65%, for the herd with a low bulk tank SCC and high incidence of CM, this was set at 60%. For the herd with a high bulk tank SCC and an average incidence rate of CM, their ideal rate was set at 40%, for the herd with an average bulk tank SCC and an average incidence rate of CM, this was set as low as 20% and for the herd with a low bulk tank SCC and an average incidence rate of CM , this was set at 10%. This study also showed that where the incidence rate of CM was low, the implementation of SDCT was more beneficial than the use of BDCT. Not only does this study highlight the cost-effective nature of SDCT but also the importance of achieving low incidence rates of CM within the herd.

A study carried out in Italy by (Zecconi et al, 2018) was used to demonstrate the use of SCC thresholds as decision-making tool for SDCT by identifying those cow that required treatment at drying off. This study also illustrates the repercussions of different selection protocols on udder health after calving while in field conditions. They examined five different thresholds, 50,000; 100,000; 150,000; 200,000; and 250;000 cells/ml and utilised a data base that recorded milk tests from 709 herds. Of the 45,682 cows' records that were surveyed, 45.7% of cows were in their first lactation, with 27.9% were in their second lactation. The remaining 26.4% were in their third lactation or higher. When analysed, they found that the overall SCC average when the last milk recording before drying off was compared to the average of all the milk test throughout the lactation, they were found to be equal. However, the difference in the last milk test before drying off and the average of all milk test carried out did differ when the primiparous cows were compared to the multiparous cows. Primiparous cows in the 50,000 cells/ml threshold were found to have a higher amount of milk tests with results below the threshold. Older cows showed to have less consistent results. The average dry period for all cows in the study lasted 62.4 days. Primiparous cows average was 58.37 days and cows in their third or higher parity with a dry period average of 67 days. When investigating the frequency of SCM in each threshold group, it was shown that significant differences in proportions were found in primiparous cow thresholds, particularly between the 50,000 cells/ml and 100,000 cells/ml threshold group. From the above result, in primiparous cows the SCC threshold suggested from this study was set at 100,000 cells/ml. There was a significant increase in the number of cows suffering with SCM after calving at 50,000 cells/ml threshold in comparison to 100,000 cells/ml threshold. For multiparous cows, a threshold of 200,000 cells/ml was suggested. (Zecconi et al, 2018)

Once again, the importance of selection criteria when, not only trying to implement SDCT, but when trying to lower the SCC of the herd is evident from the results of this study. Setting a threshold value for the SCC of either the bulk tank or individual cows is paramount when attempting to prevent a rise in mastitis cases or even ensure that milk fits the criteria to be sold and avoid fines is vital.

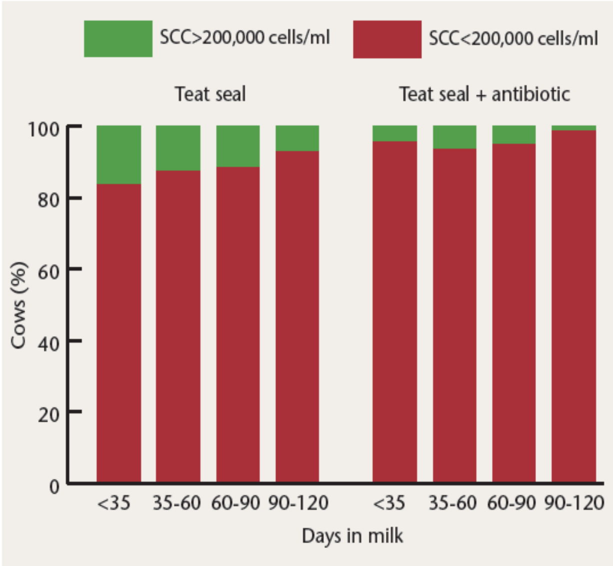
Not only is it important for the farmer to minimise costs in the current dry period but also to minimise costs in the following lactation. With an unsuccessful dry period, where there is a high incidence of CM and new infections, there tends to be a knock-on effect in the following lactation. Both milk quality and production can be heavily influenced by the previous dry period.

In a study carried out in 2015 by (Cameron et al, 2015.), the added benefit of on-farm milk culture was explored. The aim of the study was to evaluate how using a Petrifilm on-farm culture-based SDCT method would affect the milk yield and SCC in the following lactation. They surveyed 600 cows with a low-SCC, which was deemed as <200,000 cells/ml. These were all from commercials herds with a low bulk tank SCC (<250,000 cells/ml). Random selection was then carried out to determine whether the cows were given BDCT or Petrifilm-based SDCT. Composite milk samples were collected for culture before drying off, 3-4 days after calving and again 5-18 days after calving. Of the cows selected for SDCT, composite milk samples were taken before drying off and based on whether these results were Petrifilm-culture positive or negative, they would receive DCT and an internal teat sealant or the internal teat sealant on its own. A positive result was given when there was ≥5 colonies (≥50 cfu/ml of milk). BDCT with an internal teat sealant was carried out on 307 cows and SDCT with an internal teat sealant was carried out on 293 cows. Of the SDCT group, 46.8% were below the ≥50 cfu/ml threshold. Therefore, 137 of the 293 cows received only an internal teat sealant. From the composite milk samples taken, their results found that cows in their third and fourth lactation or above, had a lower milk production than those in their second lactation. They also found that calving season was a predictor for milk production. Cows calving in the summer months had a lower production rate compared to those calving in any other season. Milk production increased with the increasing duration of the dry period beyond 30 days. This may be attributed to the role of the dry period in the restoration of the cows' body and mammary tissue from the previous lactation and preparation from the upcoming lactation. Findings also showed that postpartum diseases, other than mastitis, reduced milk yield by 2.64kg per day on average. There were no significant findings in the comparison of the SCC at drying off between the BDCT group and the SDCT group. This was noted in the study, proving the necessity of having some form of protection in each quarter regardless of whether they had received DCT or not. Parity proved to influence the SCC also. Cows in their third and fourth or above lactation had a higher average SCC compared to cows in their second lactation. Cows with an intramammary infection at the time of drying off presented with higher SCC in the first 180 days of the following lactation than cows that were uninfected at drying off. (Cameron et al, 2015.)

These three studies all illustrated the importance of an appropriate selection process of cows for SDCT. The study carried out by (Cameron et al., 2015) promotes the use of on-farm culture in order to accurately diagnose cows with intramammary infection at the end of lactation. It provides sensitive results, allowing the farmer to treat these cows efficiently with intramammary antibiotics and in turn reduce their antimicrobial usage which will reduce their costs on DCT.

On-farm culture has also been used to evaluate the risk of post-calving intramammary infections and CM in the following lactation when SDCT is being implemented. Another study by (Cameron M et al., 2013) was performed in Canada, with the aim of using on-farm culturing in the process of electing to use antimicrobial treatment or not at drying off. 16 dairy herds were selected with a low bulk tank SCC, they were then randomly allocated BDCT or on-farm culture-based SDCT. The BDCT groups were treated with a DCT antimicrobial and an internal teat sealant. Whereas, the SDCT groups were given an internal teat sealant alone, provided they had a negative culture. If they had a positive culture, an DCT antimicrobial and an internal teat sealant was administered. All cows received an internal teat sealant ensuring that there was some level of protection against new intramammary infections occurring during the dry period. This was an important element so that the risk of intramammary infections at calving could be compared between the BDCT group and the SDCT groups receiving an antimicrobial and internal teat sealant or receiving only the internal teat sealant. In terms of sampling, milk sampling was carried out in an aseptic manner at drying off, between 3-4 DIM and between 5-18 DIM. For the first 120 DIM, CM cases were recorded and also sampled in order to determine the causative pathogens. Only the first CM occurrence per quarter was recorded for analysis. Results found that at cow-level, the prevalence of an intramammary infection at drying off in the SDCT group was 54.4% (162/298), with 45.6% of these cows being uninfected at drying off and having received no antibiotic. At quarter-level, the proportion found to have an intramammary infection at drying off was, however, higher in the SDCT group (15.1%) than those in the BDCT group (12.4%). From the SDCT cows that exhibited a positive culture, 67.3% of these cows had at least 1 quarter with an intramammary infection at drying off. Furthermore, the prevalence of intramammary infections post calving was insignificant when the BDCT and SDCT groups were compared, (BDCT 11.1% vs SDCT 10.6%). The majority of these new infections were cause by CNS. Within the first 120 days in lactation, 45 cases of CM were reported. 24 of these occurred in the BDCT group and 21 cases occurring in the SDCT group. When these were cultured, it was found that *E. coli, CNS and Staph. aureus* were the most frequently occurring pathogens. This study represents the success of using SDCT when in combination with on-farm culture. The accurate diagnosis from positive culture allowed the cows to be treated successfully with very little intramammary infections occurring post-calving, 10.6%. However, the study failed to represent the cases that persisted through the dry period. Due to the low bulk tank SCC of all the herds selected this allowed the prevalence of the intramammary infection at drying to be low. This outlines the importance of adhering to the selection criteria, both at herd and cow-level. CM cases that occurred during the study were the same between both groups. Additionally, quarters that were given an internal teat sealant at drying off on the basis of a negative culture were found not to increase the risk of a CM cases occurring in early lactation compared to those treated with DCT and an internal teat sealant. Throughout this study, it was also brought to light that the hind quarters were more likely to be affected by an intramammary infection post-calving that the front quarters. This suggests that closer attention to hygiene and preparation when drying off the hind quarters may be needed. In addition, cows calving in the summer and fall months were more likely to suffer from an intramammary infection than those calving during the winter. This may be linked to higher numbers of flies that are associated with summer and fall, suggesting that better fly control may alleviate this problem. On-farm culture when using SDCT allows for a more accurate diagnosis of cows suffering with intramammary infections. With the aim of SDCT to reduce the unnecessary use of antibiotics amongst livestock, this may become a key feature in dairy farming in the future. With the application of on-farm culture at quarter level this could then further decrease the excessive use of antimicrobials at drying off. (Cameron M et al., 2013)

A research group which was organised through Teagasc Ireland set out to examine the success of SDCT. The study was carried out on Moorepark Research herd, Clonakilty Research herd and Curtins Research herd. Within this trial, cows were only eligible to partake provided their SCC did not exceed 200,000 cells/ml. The cattle were randomly selected an allocated into different treatment groups. Group 1 were given teat sealant only while group 2 were given teat sealant and a long-acting antibiotic. They carried out milk sampling from each quarter to determine each individuals SCC and what pathogens may be present in each herd. Weekly milk recording was performed, samples were also carried out before treatment has been administered at drying off, samples were also carried out post-calving, two weeks post-calving and again mid-lactation. It was found that at 21 DIM, the mean SCC for cows only being given teat sealant was 101,281 cells/ml and cows given a teat sealant and a long-acting antibiotic was 73,027 cells/ml. In comparison, at 120 DIM, cows that were given only teat sealant had an SCC of 70,374 cells/ml and those cows treated with a teat sealant and a long-acting antibiotic had an SCC of 46,673 cells/ml. They concluded from their study that >80% maintained a SCC of <200,000 cells/ml with both groups of treatment. The three herds maintained a bulk tank SCC <200,000 cells/ml. From this it could prompt the discussion of reducing the blanket use of antibiotics when treating cows at drying off.



(Kennedy A et al., 2017)

Diagram 2 illustrates the results for group 1 and group 2 in terms of SCC levels recorded.

Another point that should also be explored when investigating SDCT and the factors that may influence its success are the heifers that are within these herds. Ideally, heifer mastitis should be prevented in as far as possible. These young heifers have the potential to reinvigorate the herds pathway to reducing antibiotic use on-farm. By avoiding heifer mastitis through clean housing, stress reduction and optimisation of udder health, this can allow for only a teat sealer being administered 4-6 weeks before their expected due date for calving. However, this is only possible once excellent hygiene, management and facilities are set in place. (Kennedy A et al., 2017)

A meta-analysis study was carried out on the comparative efficacy of BDCT versus SDCT. Of these herds within these studies, 4 out of 9 were commercial dairy herds, 2 out of 9 were research dairy herds. These studies were all carried out between 1975-2017. Two of these trials were carried out with a third method, being that cows did not receive any therapy at drying-off. From this study they found that when comparing BDCT and SDCT, it was found in cows that were part of the SDCT protocols, there was a higher frequency of intramammary infections occurring at calving than in the BDCT groups. They also found that the effect of internal teat sealant had immensely different effects in all groups of cows that had been surveyed. From the studies examined, that did not utilise internal teat sealant as a part of the treatment methods, SDCT groups had a higher occurrence of intramammary infections at calving. However, in those studies that did use internal teat sealant as part of their treatment methods, the intramammary infection risk at calving was considered insignificant between the BDCT and SDCT groups. (Winder CB et al., 2019)

A study that was carried out in France from 2003-2004 by (Robert A., et al., 2008), analysed the various risk factors for new intramammary infections occurring during the dry period focusing on the untreated cows from dairy herds utilising SDCT. 28 commercial herds that were implementing SDCT were used during this study. Farmers of the herds chose cattle based on individual SCC at drying off or the previous lactation and /or based on history of CM in the previous lactation or with milk yield at drying off. They examined data from 980 uninfected quarters in 347 untreated cows. It is important to note that only quarters that were uninfected at drying-off from cows that were untreated at drying-off were utilised in this study. Quarter milk samples were taken at the time of drying off and again 3 days post-calving. Intramammary infections were defined as quarters that, when milk samples were cultured, had >40 cfu/ml. New intramammary infections were defined as infections detected at day 3 after calving. They concluded that the incidence rate of new intramammary infections at quarter-level was 22.5% of all untreated cows. These infections were mainly caused by *CNS* (57%), *Cornyebacterium spp., coagulase-positive staphylococcus* ***(CPS)***, *Streptococcus uberis* and other streptococci. It was reported that the risk of a new intramammary infection occurring during the dry period was markedly higher in cows who had at least one quarter that was infected at drying off. They also documented that there was a higher risk of new intramammary infections in cows whose previous lactation lasted more than 355 days and in cows who were uninfected at drying off but had short teats. They also found that new infections were reduced in cows that had a dry period of less than 2 months. Although there was still some level of new intramammary infections occurring, the level still remained quite low. From the results collected, the necessity of good farm management surrounding lactation period-length, dry period-length and the anatomical features of cows selected are notably influential in the occurrence of new infections. (Robert A., et al., 2008)

In a 2002 study, four herds were analysed to determine the possible outcomes of SDCT on cows with low SCC and that were uninfected, in terms of new intramammary infection rate and on CM after calving. The herds used for the study had an annual bulk tank SCC of roughly 150,000 cells/ml and two of these herds were undergoing conversion to organic farming. All four teats of each cow were sampled. Sampling was carried out 1 week before drying off, at drying off, within 24 hours of calving, and 7-14 days after calving. Observations taken from this study found that no CM cases were detected during the dry period in quarters that were treated amongst any of the herds. There were notably more quarters from the untreated groups that were found to have CM in the dry period in all four herds. All CM cases diagnosed during the dry period were caused by *Streptococcus uberis*. These were all treated accordingly with a short acting intramammary antimicrobial. Of the CM cases diagnosed at calving, in the commercial herds 58 originated from the untreated group of quarters while 19 were from the group of treated quarters. In comparison to the organic herds, 38 quarters originated from the untreated groups while there were no cases of CM occurring within the treated group of quarters. *Streptococcus uberis* was the predominant pathogen resulting in the new infections at calving in both the commercial and organic herds. Amongst the quarters infected in the commercial herds, coliform bacteria were the second most causative agent. Within the organic herds, 13 new *Staphylococcus aureus* infections were identified at calving. Quarters infected with *Corynebacterium spp. or CNS* that were left untreated at drying off were found to be predisposed to new infections by *Streptococcus uberis* or coliform bacteria. Amongst the untreated groups of the commercial herds, 70.1% of the quarters infected at drying off with *Corynebacterium spp*. were still infected at calving, with an additional 1.2% of these becoming infected with CNS and 23% were infected with *S. aureus*, streptococci or coliforms. Within the organic herds, of the untreated groups 46.2% of the quarters that were infected at drying off with *Corynebacterium spp*. were still infected at calving. A further 5% were infected with CNS and 35% of quarters were infected with *S. aureus*, streptococci or coliforms. Of the treated groups, 1.6% of quarters were still infected at calving with *Corynebacterium spp*. in the commercial herds and 11.8% of quarters were still infected at calving with *Corynebacterium spp*. in the organic herds.

	IAH herds				Organic herds			
Pathogen type	Treated group	%	Untreated group	%	Treated group	%	Untreated group	%
Staphylococcus aureus	1	0.2	7	1.4	0	0	12	7.0
Streptococcus uberis	6	1.3	32	6.5	0	0	16	9.3
Streptococcus dysglactiae	0	0	3	0.6	0	0	5	2.9
Coliforms	11	2.4	12	2.4	0	0	2	1.1
Arcanobacterium pyogenes	1	0.2	2	0.4	0	0	1	0.6
Mixed infections	0	0	2	0.4	0	0	2	1.1
Total	19	4.1	58	11.8	0	0	38	22

Table 2. Pathogen prevalence from quarters affected by new infections at calving (Berry&Hillerton, 2002)

When discussing clinical incidence, the results depicted a comprehensive difference between the treated and untreated quarters in both the commercial and organic herds in the occurrence of CM in the first 3 months following calving. The incidence of CM occurring in the dry period for untreated quarters within the commercial herds was 1.5%, compared to the untreated quarters of the organic herds with 4% average. In conclusion, this study showed that DCT reduced the rate of new infection by approximately 80% and eliminated more existing infections than by spontaneous cure. (Berry&Hillerton, 2002)

When implementing SDCT, the necessity for an internal teat sealant can be questioned. In a study in 2012, 12 herds were analysed with one group would be given only an intramammary antibiotic and the other group receiving an intramammary antibiotic and an internal teat sealant. This was to investigate the udder health and CM rate during the first 100 DIM of these groups. This study formed cow-pair, meaning that one cow would receive the intramammary antibiotic alone and the other cow would then receive the intramammary antibiotic and the internal teat sealant. Milk samples were taken on the day of drying off, day 6-14 post-calving and day 35-56 post-calving. The occurrence of CM cases was observed within the first 100 DIM and cases were only recorded once in each quarter. For analysis purposes, each quarter that was dried off with an intramammary antibiotic was compared to a quarter which had been dried off with an intramammary antibiotic and a teat sealant. All cows underwent a California Milk Test **(CMT)** within the first 5 days post calving. From this, it was found that the cows receiving the intramammary antibiotic and internal teat sealant had a considerably smaller portion of negative CMT results than those only receiving an intramammary antibiotic. Based on the results from the milk samples taken on day 6-14 and day 35-56, the SCC of both groups showed a decrease. However, it did show that in milk samples taken, the group receiving only an intramammary antibiotic had higher numbers of quarters being affected by *Corynebacterium spp.* than those receiving the internal teat sealant also. The SCC of both groups presented insignificant differences; however, older cows did show to have higher SCC than those animals that were younger. When examining the CM cases during the first 100 DIM, there were 25 cases in the groups receiving only the intramammary antibiotic and 15 in the group receiving the intramammary antibiotic and the internal teat sealant. From the results of this study, it could be suggested that the need for an internal teat sealant at drying off could lower the level of new intramammary infections occurring during the dry period. Furthermore, this would lead to a decrease in the use of antibiotics to treat CM cases during the lactation period. (Mütze K. et al., 2012)

With SDCT, the use of an internal teat sealant isn’t required. However, from this study, the benefits of the internal teat sealant could be beneficial particularly for preventative measures against commensal pathogens such as *Cornyebacterium spp.* which can often predispose the quarter to infections caused by major mastitis pathogens.

When implementing SDCT on a farm, preventing the increase in CM cases after calving is one critical element. There are certain factors that can help prevent this increase through cow, farm and management factors during the dry period. In a study conducted in England and Wales, they aimed to identify any elements such as cow traits, the amenities available on farm and herd management strategies during the dry period that may increase the number of CM cases in the following lactation. In addition to these elements, they also compared cows that were kept in hosed settings as opposed to being at pasture. In order to identify on-farm amenities and management methods, interviews and questionnaires were conducted with the farmers. From these questionnaires' information regarding the general farm set-up; herd size, breed and yield, vaccination procedures used, staffing and working patterns, grouping of cows and any movement dates, bedding types, cow nutrition and water, dry-cow keeping, dry-cow pastures, calving facilities, methods used at drying-off and fly control methods. Within these categories, elements surrounding hygiene and cleaning procedures was heavily focused on. Data regarding calving, milking records, drying off were accumulated including individual cow data such as parity, yield, SCC and milk components. From their results, they found that the incidence rate of the first cases of CM in the first 30 days of lactation found that higher in housed cows as oppose to those who were kept at pasture. As found in other literature, cows who had an SCC <200,000 cells/ml prior to being dried off had a lower incidence of CM cases. Cows were in higher parities had higher incidence rates of CM, which had also been previously reported. In relation to farm management, a rise in incidence rate of CM were associated with aspects of hygiene. This was linked with the possibility of an increase in the level of pathogen in the surrounding environment. Theses hygiene aspects included execution of dry-cow treatments, housing in early and late dry period and the area used for calving were all linked to a rise in the incidence rate of CM. During this study, it was found that those cows that were kept at pasture during the dry period and those that were vaccinated against leptospirosis had a lower risk level of CM. These cows that were kept at pasture and had SDCT implemented in the herd also had reduced rates of CM. For the herds that were at pasture for the duration of the dry period, it was documented that those farms that implemented pasture rotation and only allowed a plot to be grazed for a maximum of 2 weeks, and leaving it to rest for 4 weeks had lower incidences rates of CM. Other elements such as body condition score of cows, disinfecting cubicle bedding and good drainage in the cubicles, daily cleaning of pens, fore milking cows <6 hours after calving and consistent forage for lactating cows were all considered major factors in the reduction of the risk of CM. From this study it is evident that hygiene is an integral part when lowering the frequency of CM within a herd. It also presents the arguments that allowing cattle to be at pasture for the dry period may be more beneficial than keeping them housed. However, it is understandable that not all farms have such facilities to allow this. (Green MJ. et al., 2007)

From the above studies it is abundantly clear that the introduction of SDCT to a herd is not without risk, however, it proves to be beneficial on an economic standpoint. Depending on their selection method and criteria used, the SCC of the herds should not change dramatically.

2.2. Antimicrobial usage among dairy herds

Between 2003-2015, a study was carried out to examine the intramammary antimicrobial usage on Irish dairy farms. The sales on intramammary tubes, as well as the amount of active ingredient in each product sold per year was recorded. On-farm usage was calculated using defined daily dose (DDD) calculations. Data was collected on the quantity of intramammary antimicrobial product used, represented either as a number of intramammary tubes or quantity of the active substance used (kg). The antimicrobials present in the tubes were then classified based on their importance to human health according to WHO antimicrobial classification.

- CIA (Highest priority critically important antibiotics)
    - Aminoglycosides such as dihydrostreptomycin, framyectin sulphate, kanamycin, neomycin and streptomycin.
    - Third and fourth generation cephalosporins such as cefoperazone and cefquinome.
    - Macrolides including erythromycin
    - Penicillins such as amoxicillin, ampicillin, procaine benzylpenicillin, benethamine penicillin and penethamate hydiodide.
    - Carbapenems.
- Highly important antimicrobials
    - First and second generation cephalosporins such as cefapirin, cephalexin, cephalonium

- Lincosamides including lincomycin and pirlimycin hydrochloride.
- Penicillin's including cloxacillin and nafcillin.
- Sulphonamides.
- Dihydrofolate reductase inhibitors and combinations such as trimethaprim and sulfadiazine
- Tetracyclines including oxytetracyclines.

Their results found that between 2003-2015, there was a decrease in the number of intramammary antimicrobials tubes sold in Ireland for lactation therapy, ~26,000 tubes per year. However, during this period it also found that there was an increase in the number of intramammary antimicrobial tubes sold for DCT, ~106,000 tubes per year. There was also an increase in the number of tubes of teat sealant sold, ~211,000 per year. (More et al, 2017).

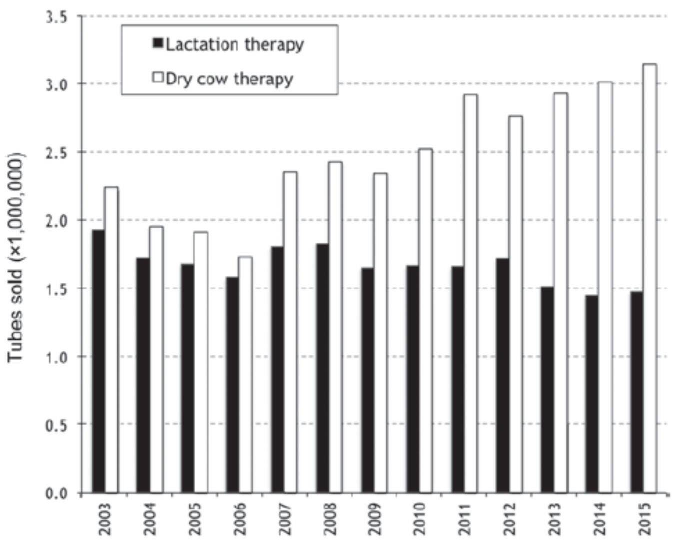


Diagram 5. Illustrates the number of antimicrobial intramammary tubes for lactating and dry cow sold in Ireland between 2003-2015. (More et al, 2017).

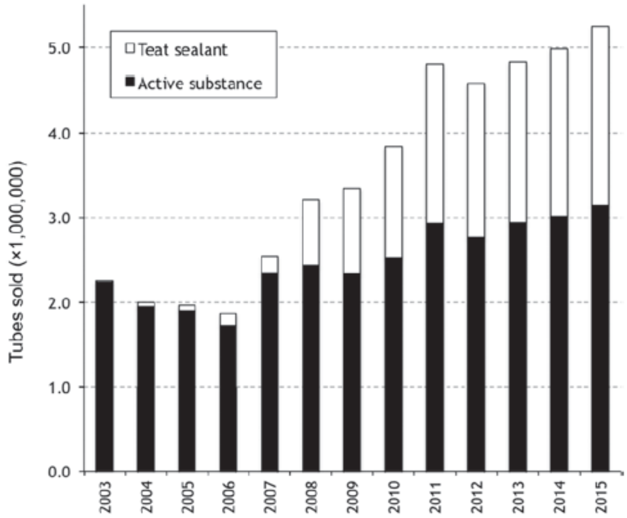


Diagram 6. Illustrates the number of dry cow intramammary tubes with either an antimicrobial or teat sealant sold in Ireland between 2003 -2015 (More et al, 2017).

Their results also found that in 2015, 6.9% of lactation therapy tubes and 5.4% of DCT tubes contained HP CIA. In relation to the amount of active ingredient sold for lactation therapy, a decrease was observed in the sale of CIA from 2003-2015. There was also an increase noted in the quantity of antimicrobials with HP CIA sold within the same time frame. For DCT, there was a decline in sales initially seen, followed by an increase in 2007 in CIA. Within 2003 to 2015 an increase was recorded in the amount of active substance containing HP CIA sold for DCT. (More et al, 2017).

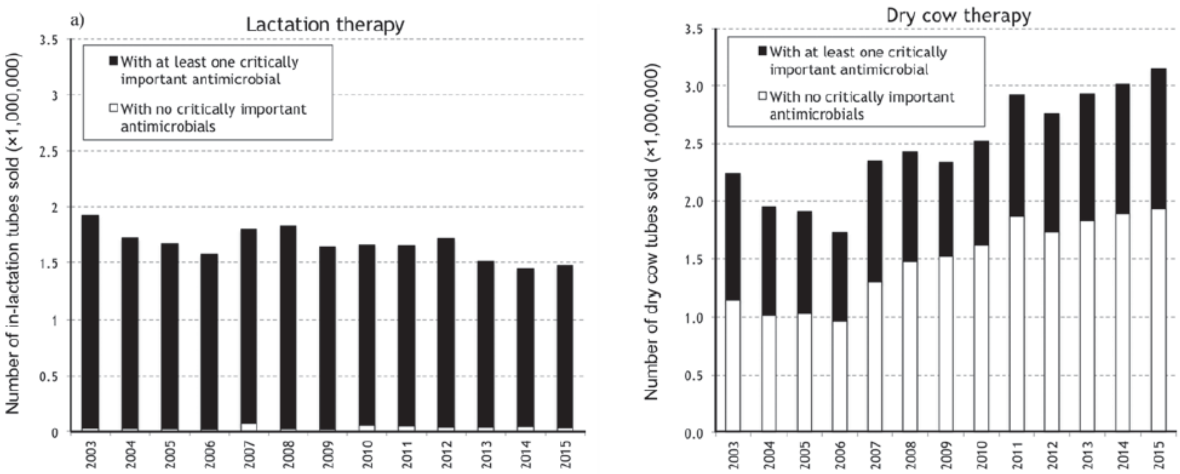


Diagram 6a, 6b. These diagrams compare the sale of products containing at least 1 or no CIA between lactating cow and dry cow therapy. (More et al, 2017).

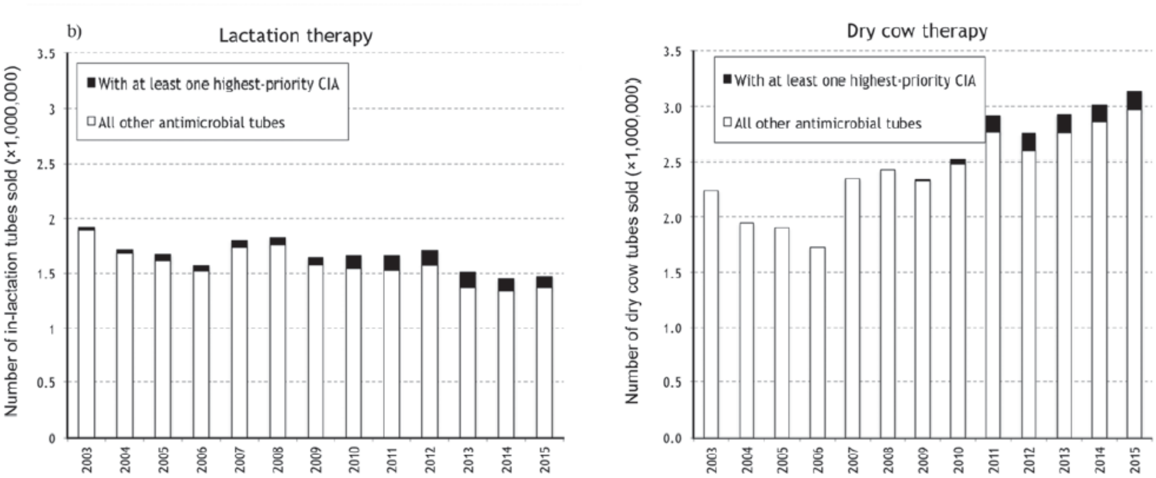


Diagram 7a, 7b. These diagrams compare the sale of products containing at least 1 or no highest priority CIA between lactating and dry cow therapy. (More et al, 2017).

The data collected for this study estimated that the usage of antimicrobials for lactation therapy from 2003 to 2015 had decreased from 1,993 to 1,398 DCDvet per 1,000 animals per year, with an annual decrease of 663 to 466 DCDvet per 1,000 animals per year. Additionally, it was documented that there was an estimated increase in the usage of antimicrobials for DCT from 794 to 1,022 DCDvet per 1,000 animals per year in this same time frame. (More et al, 2017).

Although, there is evidence shown for the reduction in the usage of antibiotics for both lactation therapy and DCT, there remains an obvious overreliance on the use of antimicrobials. The use, in particular, of HP CIA needs to be dealt with and brought under control.

A study was conducted in Austrian dairy farms, where the aim was to analyse their antimicrobial usage which was calculated by Defined Course Doses **(DCDvet)/**cow/year. The analysis was done based on production system, organic versus conventional, and the use of blanket versus selective DCT. The authors sought to prove that the use of SDCT led to an overall reduction in antimicrobial use. It is important to note that in Austria there is a strict control in place over the distribution of antimicrobial substances among food-producing animals. All antimicrobials must be procured from the veterinarian and are prohibited to be sold over the counter. In conjunction with this, both veterinarians and farmers must keep a record of all treatments administered to food-producing animals. Antimicrobials must only be dispensed to farmers who are part of the Austrian Animal Health Service and have completed a training course for administrating medicines. They utilised data collected from 17 veterinary practices on a year-long basis of treatments administered for udder disease. A total 193 dairy farms were then nominated by the veterinary practices, with all farms being enrolled in the national milk recording service and the Austrian Animal Health Service. One DCDvet was classed as four intramammary injectors, irrespective of the active ingredient or concentration. A farm management questionnaire was sent out to all farmers in order to divide up the farms appropriately for analysis based on blanket or selective DCT and conventional or organic farms. From the responses of the questionnaires, it was found that 57% of the conventional farms used BDCT. 41% of conventional farms implemented SDCT.

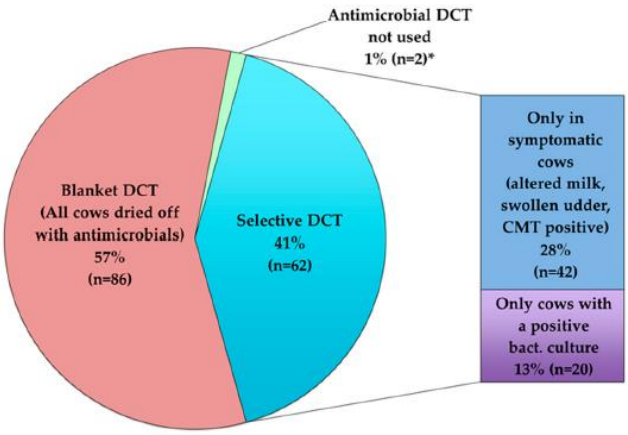


Diagram 8. Commercial herd BDCT vs SDCT breakdown. (Firth et al., 2019)

This 41% was then subdivided as 28% were cows showing clinical symptoms and the remaining 13% were cows that had resulted in a positive bacterial culture.

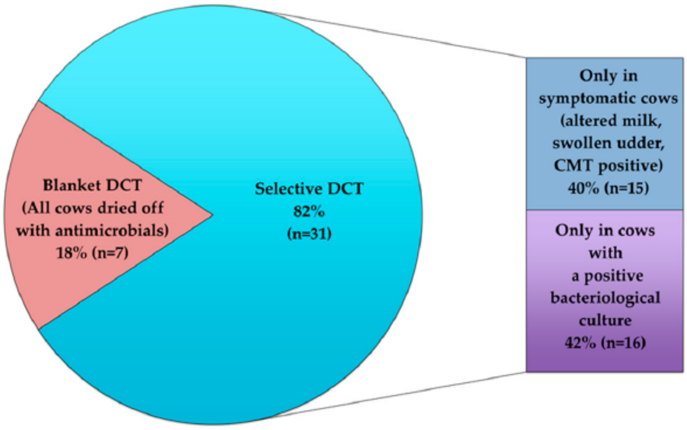


Diagram 9. Organic herd BDCT vs SDCT breakdown. (Firth et al., 2019)

Amongst the organic farms, 82% were using SDCT. 42% of that were cows being treated based only on a positive bacterial culture and 40% only using antimicrobials in symptomatic cows. The remaining 18% of organic farms were carrying out BDCT. The results of the calculated DCDvet/cow/year found that the mean for BDCT was 0.86 DCDvet/cow/year. For SDCT, the mean worked out as 0.54 DCDvet/cow/year. This shows an impressive decrease in antimicrobial usage when SDCT was implemented. When comparing the DCDvet/cow/year figures based on production system, it showed that conventional farms had a mean of 0.70 DCDvet/cow/year whereas organic farms had a mean value of 0.64 DCDvet/cow/year. Therefore, this depicts the, somewhat, insignificant difference between the antimicrobial usage for DCT on the conventional and organic farms. The conclusion of this study stated that from the data collected, there was a 37.2% decrease in the DCDvet/cow/year proving that there a definite reduction in antimicrobial usage when SDCT is carried out, regardless of the production system that is in place on the farm. (Firth et al., 2019)

As part of a meta-analysis study carried out, data bases were searched in order to portray the most topical arguments being made in the role of antibiotic use in agricultural and its link with antibiotic resistance. The aim of the study was to propose strategies in order to bridges gaps in information on the topic. From three online databases of scientific literature, they reported that in studies that have been documented, the risks to human health or the benefits to animal production have not been well studied. Both among international and national policies, there is a strong lack of uniformity with the subject. It was noted that even with high-level antibiotic use in food producing animals, there is a lack of data in regards to its quantity and patterns of use. From the literature they analysed, they found that there was significant interest in therapeutic use of antibiotics. However, there was lack of investigations into both prophylactic and subtherapeutic uses of antibiotics. In recent studies carried out by the Union of Concerned Scientists which act as an advocacy group for the reduction in antimicrobial use in food producing animals suggested that 24.6 million pounds of antimicrobials for nontherapeutic uses are used in chicken, cattle and swine. When examining literature based on the association between antimicrobial use in food producing animals and human antimicrobial resistance, it was documented that antimicrobial resistant bacteria based in animal origin were shown in farming and livestock environments and meat products sold to retail units. In the comparison of risks and benefits of antimicrobial use in food producing animals, they recorded that it can cause both direct and indirect effects on human health. Direct effects being that cases are linked with contact with these animals and indirect through the ecosystem such as the water and soil. The authors recognise there is still a vast area in the subject still to be studied. In order to bridge some of these gaps in knowledge they provide three suggestions to aid this. Firstly, a scientific agenda needs to be assembled in order to identify missing data. They suggest this can be done through specific study designs and methods. Although there is plenty of literature on the subject of antimicrobial use in animals and its effect on human health, there is a severe lack of uniformity and harmonisation in order to do this on both national and international level. Secondly, they proposed the funding of agricultural research to compliment the research agendas. It was noted that there is a severe lack of funding for agricultural research and the investment by different organisations is wildly variable. From their research, the found that in 2007 the U.S. Department of Agriculture supplied $32 million for external research funding. Whereas, in the same year the National Institutes of Health dedicated $800 million to research into antimicrobial resistance. The U.S. funds 70-80% of the biomedical research being carried out worldwide and given the gravity of the ever-growing problem associated with antimicrobial resistance, their support must equate to the extent of the issue. Finally, they sought to deal with the constraints surrounding the collection of data in order to produce studies on antimicrobial usage. The authors recognised that this is in relation to political, economic and social situations that limits the availability of this data. As this information is only available and published on a voluntary basis, in order to assess the full extent of the problem and have any hope to tackle the issue, appropriate data and cooperation is needed. (Landers T.F, et al.,2012)

2.3. Antimicrobial resistance and susceptibility

A study published in 2020, was used to demonstrate antimicrobial susceptibility of pathogens responsible for clinical mastitis in Europe. The study was used in conjunction with three monitoring periods between 2002-2016. From 2002-2006, the three major mastitis pathogens (*Escherichia coli, Staphylococcus aureus, Streptococcus uberis*) were examined. The second period extended from 2009-2012, where *Klebsiella spp., coagulase-negative Staphylococcus spp.* and *Streptococcus dysgalactiae* were also studied. The final part of this study was carried out from 2015-2016. In the third instalment of this study, the cows were examined before being treated for acute CM from eight countries within Europe. This data also included information regarding *Streptococcus agalactiae, Trueperella pyogenes* and *Corynebacterium spp*. The purpose of the three monitoring periods was to analyse the resistance and how it has developed throughout this time. Milk samples were taken from cows that were suffering with acute local or systemic signs of CM and/or macroscopically abnormal milk secretions. These cows had not been given any antibacterial treatment for at least 3 weeks. A single laboratory was used to carry out susceptibility testing of antimicrobials and determine the minimal inhibitory concentrations **(MIC)**. A total of 26 antimicrobials were used for this study. When the isolates were being detected, gene screening was carried out to identify *ESBL/AmpC* and *mecA/mecC*. Their study found that, in total, 1244 isolates were procured from acute cases of mastitis.

- *E. coli*: 225
- *Klebsiella spp*: 70
- *S. aureus*: 247
- *Coagulase-negative Staph*: 189
- *Streptococcus uberis*: 208
- *S. dysgalactiae*: 132
- *S. agalactiae*: 44
- *T. pyogenes*: 94
- *Corynebacterium spp.*: 35

Among the Gram-negative mastitis pathogens, *E. coli* was found to have the largest number of isolates. Low MIC90 values were demonstrated by fluoroquinolones and fourth generation cephalosporin, cefquinome. This study found that of 4% of *E. coli* and 2.9% of *Klebsiella sp* were *ESBL/AmpC* producers. *ESBL/AmpC* producers showed to frequently show resistance against β-lactams such as cephalosporins as well as fluoroquinolones, aminoglycosides and trimethoprim/sulfamethoxazole. Oxacillin resistance was the most frequent resistance phenotype that was found in this study. Oxacillin resistance was associated with the *mecA* gene in 15 methicillin-resistant strains; 2 S. aureus strains and 13 CNS. With tetracycline resistance, in this study it was found to be at 37.5%. The authors noted that there has been a significant increase in the resistance rates against these antimicrobials compared to their studies carried out in 2009-2012. (Garch et al., 2020)

This study shows the frightening rise that is occurring in antimicrobial resistance across the board in all antimicrobial groups. Tetracycline resistance showing an average of 37.5% over all the antibiotic groups. Although it may not be the first choice for treatment, its use may be discouraged due to these findings as the risk of re-infection or its failure to treat the mastitis appropriately is higher than with other antimicrobial families.

Over a 10-year period, a study was carried out on dairy farms in France with the aim of estimating the levels of antimicrobial resistance of *Streptococcus uberis*, *Escherichia coli* and *coagulase-positive staphylococci*. These are the three main offending bacteria when it comes to mastitis in dairy cattle. These pathogens were examined over 10 years to discover whether trends were discovered over this period.

Data was sourced through a French national surveillance network for AMR in pathogenic bacteria, RESAPATH. Data involving the 3 pathogens (*Strep. uberis, E. coli and CPS*) were collected from RESAPATH. Antibiotics used for antibiograms were chosen based on their relevance to both human and veterinary medicine. Analysis for multidrug resistance was carried out on isolates, isolates that were found to be resistant to at least one antibiotic in 3 or more antibiotic classes were deemed as multidrug resistant. In total, 27,888 antibiograms were found to be connected to mastitis in dairy cattle as 1 of the 3 most common pathogen species were isolated and they included at least one of the selected antibiotics. It was found that 49.7% of these involved *S. uberis*, 25.4% involved *E. coli* and 24.9% involved *CPS*. As regards trends in antimicrobial resistance, *S. uberis* was found to have increasing levels of AMR in all antibiotics tested. There was a linear pattern depicted for its resistance against tetracycline, starting from 15.7% in January 2006 rising to 20.4% in December 2016. Other antibiotics were found to be non-linear in pattern. Trends for amoxicillin, enrofloxacin, SXT and gentamicin with *E. coli* were found to be stationary over the 10-year period. There were noticeable fluctuations seen with tetracycline increasing from 19.5% in January 2006 to 42.4% in July of 2009 before decreasing again to 20.6% in December of 2016. Trends for marbofloxacin, tetracycline, erythromycin and gentamicin were found to be stationary throughout the 10-year period. The resistance against SXT was found to be in a decreasing linear fashion, declining from 2.1% in January 2006 to 0.8% in December. Lincomycin was found to be similar, declining from 5.8% in January 2006 to 3.5% in December 2016. In terms of multidrug resistance, this occurred in 14.5% of *S. uberis*, 7.6% of *E. coli* and 3.6% of *CPS.* From this study, there were some altering trends in antibiotic resistance but the majority showed no significant increase. Regardless of this, there are still some worrying trends that were shown. Particularly with the high-level resistance seen with *S. uberis* against enrofloxacin and *E. coli* against 3rd generation cephalosporins. The WHO have classed 3rd generation cephalosporins and quinolones as highest priority critically important antimicrobials for human medicine meaning that they should be used prudently in both human and veterinary medicine. This study, however, may not be wholly accurate due to the inability of to distinguish between the CPS species that were identified. As well as this, it important to note that overestimations could have been made in terms of resistance as isolates that were labelled as “intermediate” were grouped together with the resistant isolates. Some of the results contradicted other studies that had been carried out. For example, from this study it was found that *S. uberis* resistance to oxacillin was low at 2.2%. On the contrary, another French study performed between 2007-2008 found the resistance to oxacillin to be higher at 12.6% (Botrel et al., 2010). However, the other proportions of resistance for CPS isolates were found to be consistent (Botrel et al., 2010) (Boireau et al., 2018).

Regardless, trend-mapping of mastitis pathogens and their resistance may be hugely beneficial in the efforts to deter AMR. Its depiction through visual representation may finally be enough for the public to grasp the concept and portray its severity as a topic.

In 2018, a study was performed with the objective of observing herd-level associations between antimicrobial usage and the frequency of antimicrobial resistance along with the antimicrobial resistance genes in non-aureus staphylococci (NAS) according to antimicrobials and their routes of administration. 1,702 NAS isolates were acquired from 89 herds and were analysed against a panel of antimicrobials to achieve an accurate phenotypic AMR profile. These antimicrobials included

- *Ampicillin*
- *Chloramphenicol*
- *Ceftiofur*
- *Cephalotin*
- *Ciprofloxacin*
- *Clindamycin*
- *Daptomycin*
- *Erythromycin*
- *Gentamicin*
- *Levofloxacin*
- *Linezolid*
- *Moxifloxacin*
- *Nitrofurantoin*
- *Oxacillin + 2% NaCl*
- *Penicillin*
- *Penicillin/Novobiocin*
- *Pirlimycin*
- *Quinupristin/Dalfopristin*
- *Rifampin*
- *Tetracycline*
- *Tigecycline*
- *Trimethoprim/Sulfamethoxazole*
- *Vancomycin*

An isolate was labelled as being "multidrug resistant" if they were resistant against 2 or more antimicrobial classes. Their results concluded that tetracycline, penicillin, erythromycin, pirlimycin, chloramphenicol and clindamycin presented the highest frequency in resistance. Furthermore, it was discovered that no NAS isolate presented any resistance to gentamicin, linezolid, cephalothin, vancomycin, levofloxacin, moxifloxacin, ciprofloxacin or nitrofurantoin. 23 isolates showed resistance against the penicillin-novobiocin combination. 5 NAS isolates showed resistance against SXT and 5 isolates were also resistant to daptomycin. 8.8% (150) isolates were found to have multidrug resistant phenotypes. When examining the gene sequencing of the isolates, 405 were investigated. 31.6% of isolates were encoded with the gene for Macrolide-resistance with *mphC erm* or *msrA*. When antimicrobial usage was investigated, at least 80 herds had at least 1 antimicrobial daily dosage (ADD) with penicillins. The average antimicrobial drug usage rate, which was defined as the ADD/cow/year, was 3.7. Antimicrobials such as macrolides, phenicol's, aminoglycosides and fluoroquinolones were rarely used. In terms of the relationship between antimicrobial usage and antimicrobial resistance, the total antimicrobial usage had a positive correlation with the prevalence of multidrug resistance in NAS. Only systemic routes of administration were linked to this prevalence of multidrug resistance in NAS. In particular the systemic use of penicillin's, macrolides, and 3rd generation cephalosporins showed an association with the frequency of resistance against their specific drug classes. It was found that with each additional ADD of tetracyclines/cow/year through systemic administration resulted the occurrence of *erm* genes in NAS to be 10.63 times higher. (Nobrega et al.,2018)

From this study, there is compelling evidence to show that the prevalence of antimicrobial resistance in NAS is attributable with the systemic use of antimicrobials in dairy herds. Drug-specific antimicrobial resistance linked with the systemic use of penicillin's, 3rd generation cephalosporins and macrolides. This is particularly alarming as both 3rd generation cephalosporins and macrolides are considered two of the highest priority antimicrobials by the WHO. The authors predicted that the link between antimicrobial usage and antimicrobial resistance in NAS was due to the antibiotics being administered systemically at sub-therapeutic levels allowing prolonged bacterial exposure to the antimicrobial. This information once again supports the reduction of antimicrobials amongst livestock.

It is estimated that from 2010 to 2030, global consumption of antimicrobials in livestock production will increase by two thirds and that it will double in Brazil, Russia, India, China and South Africa. (Van Boeckel et al., 2015)

The death of nearly 23,000 people a year in the United States is estimated to be caused by antimicrobial resistant bacteria, including methicillin-resistant S. aureus (MRSA) strains, which are responsible for almost half of these fatalities. (Centre for Disease Control and Prevention. 2017). Antimicrobial resistance is an increasing threat to public health globally, and it is widely accepted that antimicrobial usage, both in human and veterinary medicine, accelerates the development of AMR (O'Neill. J, 2016). Regardless of this point of view, the consumer and societal demands are evolving which is hugely impacting the use of antibiotics in food producing animals, particularly the prophylactic use. In order to tackle the global issue of antimicrobial resistance, the overuse of antibiotics in food producing animals and rising antimicrobial resistance emergence in cattle needs to be explored.

2.4. Farmers attitude to SDCT

Amongst other aspects, as part of the implementation of SDCT it is essential that the farmers are willing to embrace the method and allow time for their herd to adapt. Without cooperation from farmers, no doubt it could potentially result in further losses, both financially and within the herd. In order to get a greater understanding of farmers perspective toward SDCT, a study was conducted in the Netherlands. It is important to remember that since 2013, the preventative use of antibiotics is prohibited, therefore meaning the use of BDCT was no longer permitted. The aim of the investigation was to provide insight into the degree of implementation of SDCT in 2013, the method and process of selection of cows and the correlation between SDCT and udder health and antimicrobial usage and finally the farmers attitude to SDCT. An online questionnaire was distributed to farmers. From here, the herds were divided into 3 groups depending on their dry cow method and the percentage of cows dried off using antimicrobials. Group 1 consisted of herds that used BDCT. The remaining herds were divided based on the percentage of cows that were dried off with antibiotics. Group 2 were the herds found to be drying off a higher number of cows with antibiotics and group 3 being those herds with a lower antibiotics usage at drying off. Of the 177 herds surveyed, 25% of these were found to be using BDCT. The remaining 75% that had introduced SDCT showed the mean percentage of cows dried off with antibiotics was 63%. As regards methods of selection criteria for SDCT, 70% of farms used the SCC history from the previous lactation. From these farms 36% of them were found to be basing their decision on SDCT usage from the SCC from the cows last milk recording. 27% of farms were found to use the CM history in the previous lactation as a deciding factor. 14% of farms were also found to be using the milk yield on the day of drying off as part of the criteria. In terms of antibiotic usage, when farmers were applying DCT, 94% of farmers chose to administer antibiotics into all 4 quarters. 64% (114) of all the farmers that contributed to the study used internal teat sealants. With 52 of these 114 farmers using an internal teat sealant on all cows. A higher percentage of the low level SDCT herds (Group 3) were found to use internal teat sealants than compared to farmers using BDCT. The high and low level SDCT herds, group 2 and 3 respectively, showed to have insignificant differences on internal teat sealant usage. When examining the attitude of the farmers based on the answers they gave in the survey, 87% of farmers concurred that the reduction and restriction in antimicrobial use amongst animals was essential. Along with this 87% of farmers felt they could still be a good farmer without the reliance of antibiotics. 85% of farmers also either strongly agreed or agreed that the veterinarian plays a vital role when considering SDCT use. When asked about what would be the most beneficial aspect of reducing their antimicrobial usage, "financial consequences" and "improving public health" were among the most common points. However, in terms of negative points, these varied depending on which group the farmers were a part of. 25% of farmers mentioned the "uncertainty of a cow recovering without antimicrobials" and there being a "higher risk of sick cows" as the main negative points. Although farms in the Netherlands are now obliged to used SDCT, the attitude and reception of its implementation appears to be extremely promising. As financial costs are considered by the farmers to be one of the main driving points in the acceptance of SDCT, in the long run this would reflect in the economics of these farms. In term, the hope would be for this to encourage more farmers to adopt SDCT and in term reduce the overall use of antimicrobials and their costs. (Scherpenzeel et al., 2016)

3. Thesis Statement

The purpose of my thesis will be to examine the use of SDCT on dairy farms in Ireland, in particular their selection process of cows for antimicrobial therapy at the time of drying off. I will explore how theses farms have fared since the implementation of SDCT, focusing on their average SCC, both recent and persistent mastitis infection rates and the frequency of new infection occurring after the dry period. Following this I will evaluate the farms reduction in AMU and the economic impacts that may follow SDCT.

4. Materials and Methods

"Cellcheck" is the national mastitis control program in Ireland which is coordinated and facilitated by AHI to manage SCC issues on farm. Their main aims are to reduce mastitis cases within Ireland, lower bulk tank SCC and reduce the use of antibiotics at drying off. AHI and "CellCheck" offer farmers a consultation with a trained veterinarian to examine their farming system with the aim of introducing SDCT. These 4 farms used the "CellCheck" criteria for carrying out SDCT which are as follows,

- A bulk tank milk SCC average of <200,000 cells/ml over the last 12 months.
- At least four whole herd milk recordings in the last 12 months.
- Accurate documentation of clinical and subclinical mastitis cases.
- Dry period new infection rate is <10%
- High levels of hygiene at drying off, during the dry period and surrounding calving.
- Suitable cows should have <100,000 cells/ml throughout the lactation and no history of clinical mastitis during that lactation

4.1. "CellCheck" data interrogation on the four farms using SDCT

I used data collected from 4 farms in County Meath Ireland, who were implementing SDCT. These 4 herds implemented SDCT for 2 years, beginning 2019. All 4 farms are spring calving herds and are grazing herds that are housed over the winter during the dry period. I also included data from 2018 in order to show any positive or negative trends since implementing SDCT. I examined the data from their regular milk recordings, including the key "CellCheck" report. I used reports issued in the same time frame each year. These reports provided the following information,

1. Average SCC of the herd.
    - The target is set at <200,000 cells/ml
2. The percentage of cows >200,000 cells/ml.
    - The target is set at <15%
3. The percentage of recent infection rates, which is defined as animals who had an SCC of <200,000 cells/ml at the previous milk recording, but at the current milk recording have an SCC >200,000 cells/ml
    - The target is set <7%
4. The percentage of persistent infections, which is defined as those animals who had an SCC >200,00 cells/ml at both the previous and current milk recording.
    - The target is set at <7%
5. The percentage of dry period new infection rate.
    - The target is set at <10% for cows and <15% for heifers
6. The percentage of dry period cure rate, which is defined as the % of cows that had an SCC >200,000 cells/ml at the milk recording prior to drying off and at the first milk recording after calving have an SCC <200,000 cells/ml.
    - The target is set at >85%

Access to SCM mastitis information was available on all the farms, however only one farm provided CM records and data regarding those cows that were dried off with or without antimicrobials. From this one farm, I examined the financial impact SDCT has had since its introduction.

I conducted phone interviews with the farmers. During these interviews I asked about their drying off process, the housing of the cattle and hygiene on the farm. I also spoke with them as to why they initially sought to introduce SDCT to their herd. I also asked about any reservations or fears they had when implementing SDCT.

5. Results

5.1. Farm 1

Farm 1 analysis is summarised as follows in table 4,

	2019	2020
No. of animals recorded	304	312
Average SCC	126,000 cells/ml	97,000 cells/ml
% of herd >200,000cells/ml	5.9% (18 animals)	7% (22 animals)
Recent infection rate	4%	3%
Persistent mastitis infection rate	3%	4%
New infection rate over the dry period	Cows – 8% Heifers – 12%	Cows – 8% Heifers – 0%
Cure rate over the dry period	62% (8/13 animals being cured)	50% (2/4 animals being cured)
Avoidable milk loss.	76.9 L/Herd/Day	73.3L/Herd/day

Table 3: A summary of the findings on farm 1

In table 4 it shows that in 2019, of the 18 animals that had an SCC >200,000 cells/ml, 4 of them were in their first lactation. 1 animal was in its 2nd lactation and the remaining 13 animals were in their 3rd lactation or above. The CM rate in the first 100 DIM showed that 8.5% of the herd suffered with CM, there were 37 quarters cases in 26 animals. 16 of these 26 animals had been dried off with an intramammary antibiotic and a teat sealant, with the remaining 10 occurring in animals that had been dried off with a teat sealant alone. 13.8% (10/72) of the animals that were dried off with teat sealant alone suffered with CM in the first 100 DIM, while only 6.89% (16/232) of animals dried off with an antibiotic and a teat sealant suffered from a CM case.

In 2020, of the 22 animals that had an SCC >200,000 cells/ml, 1 animal was it their first lactation and one animal was in their 2nd lactation. The remaining 20 animals were in their 3rd lactation or above. The CM rate in the first 100 DIM showed that 7.3% of the herd suffered from a case of CM, there were 25 quarter cases in 23 animals. 13 of the 23 animals had been dried off with an intramammary antibiotic and a teat sealant, the remaining 10 animals received only a teat sealant at drying off.

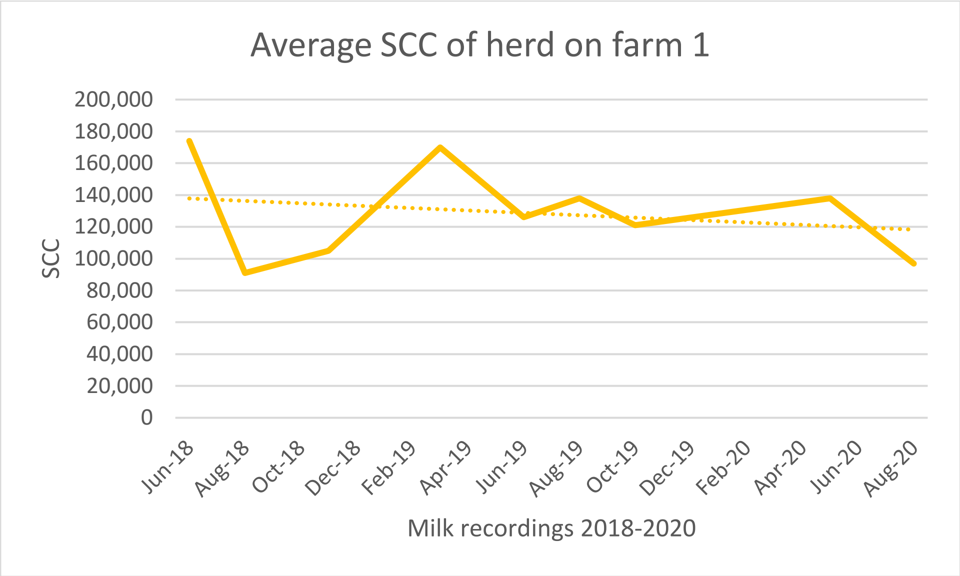


Diagram 10: Average SCC of herd on farm 1.

From diagram 10, there is a clear decreasing trend being shown by the SCC in the herd.

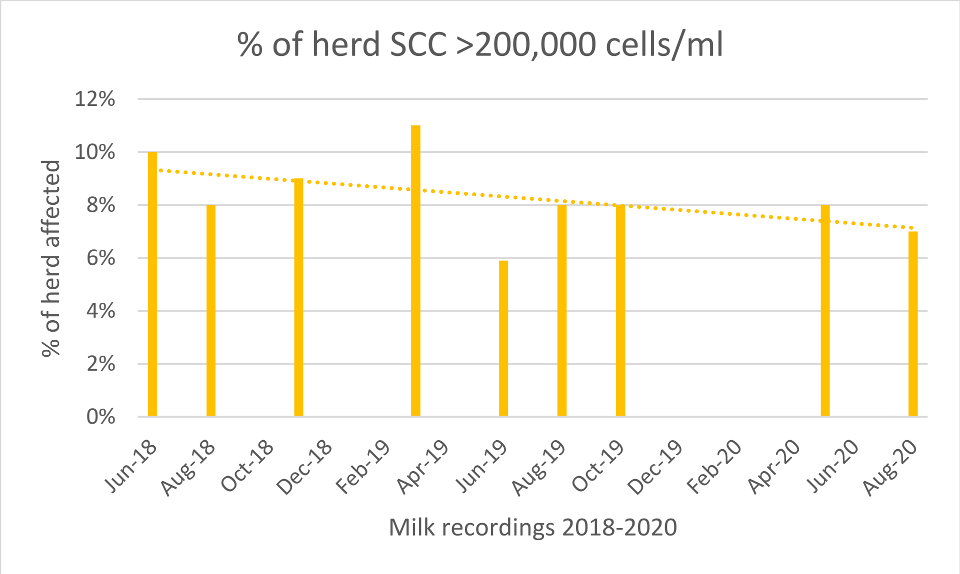


Diagram 11: The percentage of the herd with an SCC >200,000 cells/ml on farm 1.

From diagram 11, although it is not linear, there is a decreasing trend in the percentage of the herd that have an individual SCC >200,000 cells/ml. Again, there is a sharp increase at the 4th recording, which also corresponds with the increase in the herds average SCC.

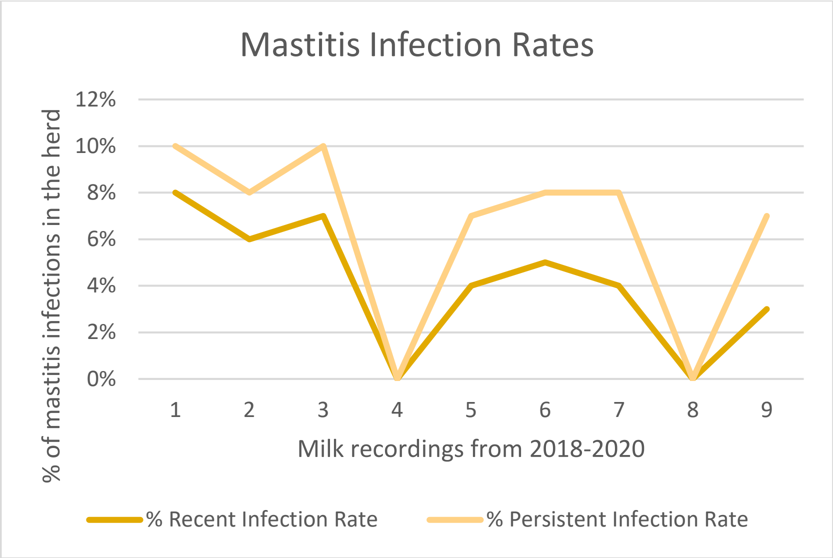


Diagram 12: The recent and persistent mastitis infection rates on farm 1.

There has also been a slow decline in the percentage of the herd with, both, recent mastitis infections and persistent mastitis infections, which is illustrated by diagram 12. There was no data recorded during two of the milk recordings, resulting in no data at two points of the chart.

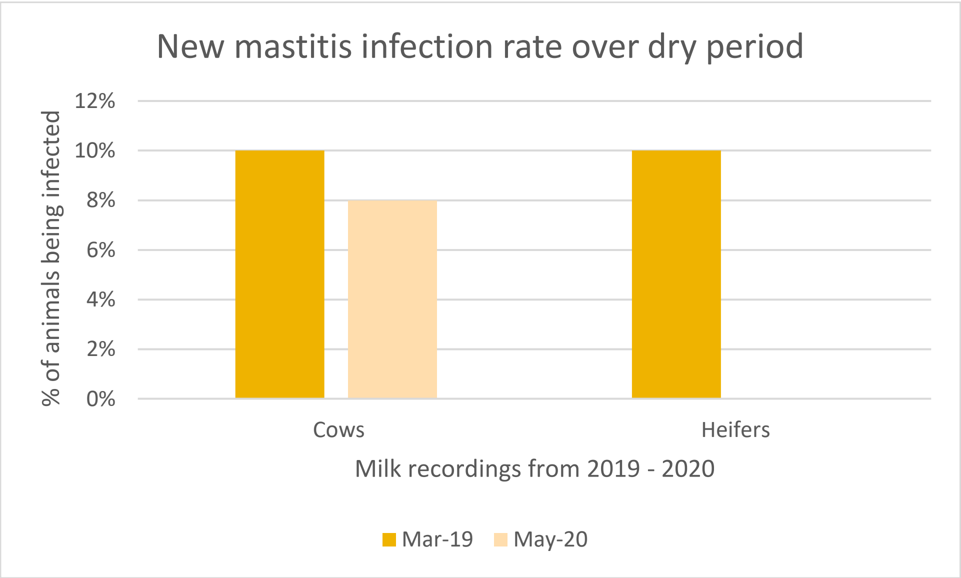


Diagram 13: The new mastitis infection rate over the dry period on farm 1.

In diagram 13, it shows there has been a reasonably constant percentage of cows being newly infected with mastitis after the dry period. Within the Animal Health Ireland "CellCheck", the target for the new infection rate in cows is set at 10%. Therefore, remaining around 8% for a new mastitis infection rate in cows is commendable. The new mastitis infection rate in heifers had a rapid increase during 2019, however, it still remained below the "CellCheck" target of 15% for heifers.

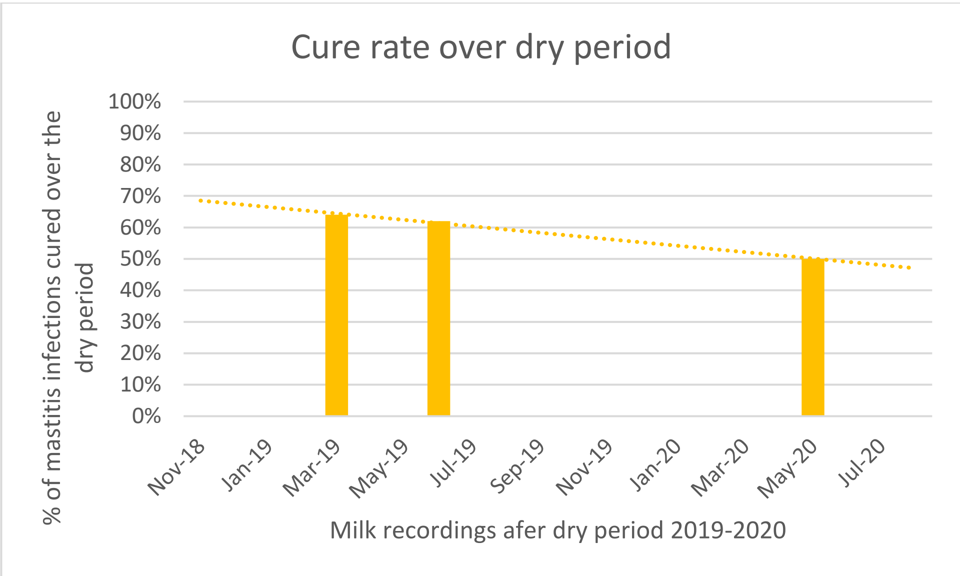


Diagram 14: The cure rate of mastitis infections over the dry period on farm 1.

The cure rate over the dry period has disimproved by 65% to 50% being illustrated by diagram 14. The target set by AHI "CellCheck" is >85%.

5.1.1. <u>Reasons for implementing SDCT</u>

- Lowering the risk of antibiotic residues in the bulk tank.

By lowering the antibiotics used at drying off, this in turn lowers the risk of antibiotics residues occurring in the bulk tank the following spring. The risk of penalties from the dairy companies is reduced by this.

- Lowering the quantity of antibiotic contaminated milk being fed to calves.

As the calves are fed a combination of the discarded milk and milk replacer, by lowering the quantity of antibiotic contaminated milk this would mean there is a reduced risk of the calves developing antibiotic resistance early in their lives.

- Legislative change.

Due to legislative changes taking place in January 2022, it will mean that the preventative use of antibiotics will no longer be authorised. As a result of this the farmer felt it "is better to get ahead of the game and slowly introduce it and get it right rather than rush it", which could result in catastrophic results for farmers financially.

- To help prevent and reduce resistance within the herd

In terms of method for selecting cows, this farmer set a limit of 50,000 SCC cells/ml. By doing this the farmer said he "eliminates cows that might be on the border, particularly if they have 2 or 3 good quarters and 1 infected quarter". After the initialisation of SDCT within the herd, the farmer noted "There were no major increases in CM cases".

5.1.2. Cost of CM treatment and drying off

When examining costs for treating CM case during lactation, the standard treatment or ADD was 1 syringe/quarter every 12 hours after milking for 3 consecutive milking's. This would result in 12 antibiotic lactating cow tubes/cow. This farmer treats CM cases using *Synulox* tubes with amoxicillin and clavulanic acid as the acting ingredients and *Terrexine* tubes with cefalexin monohydrate and kanamycin monosulphate as the acting ingredients. *Synulox* tubes are €3.20c per tube and the *Terrexine* tubes are €2.55c per tube, which would result in a total €53.67c to treat a case of CM in a lactating cow. In 2019, with 37 cases of CM in the first 100 DIM, this would result in a total cost of €1,985.79. In 2020, with 25 cases of CM in the first 100 DIM, this would result in a total cost of €1,341.75c. As there were lower CM cases in the first 100 DIM in 2020, there was a saving of €644.04c by the farmer. Management in the dry period is a hugely influential factor on the SCM and CM rate in the following lactation. The farmer preferred using *Cepravin DC* in high risk cows as it had a more persistent activity. *Bovaclox DC* was used in low risk cows. When calculating the cost of drying off a cow, for cows who were considered "H" or high, they would be given *Cepravin DC* intramammary tube which is €2 per tube. The cows considered "L" or low, would be given *Bovaclox DC* tube, which is €1.40c per tube. Every cow would receive a teat sealer, costing €1.30c per tube. To dry off the herd it cost €2932.80c in 2019 as there were only 72/304 animals receiving only a teat sealant. In 2020, 42.9% of the herd were to be dried off with only a teat sealant. This would mean that 178/312 animals to receive an intramammary antibiotic and teat sealant. This would cost €2672 to dry off the entire herd, resulting in €260.80c being saved in 2020 drying off costs.

5.2. Farm 2

Farm 2 analysis are summarised as follows in table 5,

	2019	2020
No. of animals recorded	90	151
Average SCC	124,000 cells/ml	151,000 cells/ml
% of herd >200,000 cells/ml	11% (10 animals)	10% (15 animals)
Recent infection rate	11%	7%
Persistent mastitis infection rate	1%	4%
New infection rate over the dry period	Cows – 15% Heifers – 0%	Cows – 0% Heifers – 0%
Cure rate over the dry period	0%	0%
Avoidable milk loss	25L/Herd/day	36.7L/Herd/day

Table 4: A summary of the findings on farm 2.

In 2019, 10 animals that had an SCC >200,000 cells/ml. 2 of these animals were in their 1st lactation and 2 animals were in their 2nd lactation. The remaining 6 animals were in their 3rd lactation or above.

In 2020, 15 animals that had an SCC >200,000 cells/ml. 4 of these animals were in their 1st lactation and 4 were in their 2nd lactation. The remaining 7 animals were in their 3rd lactation or above.

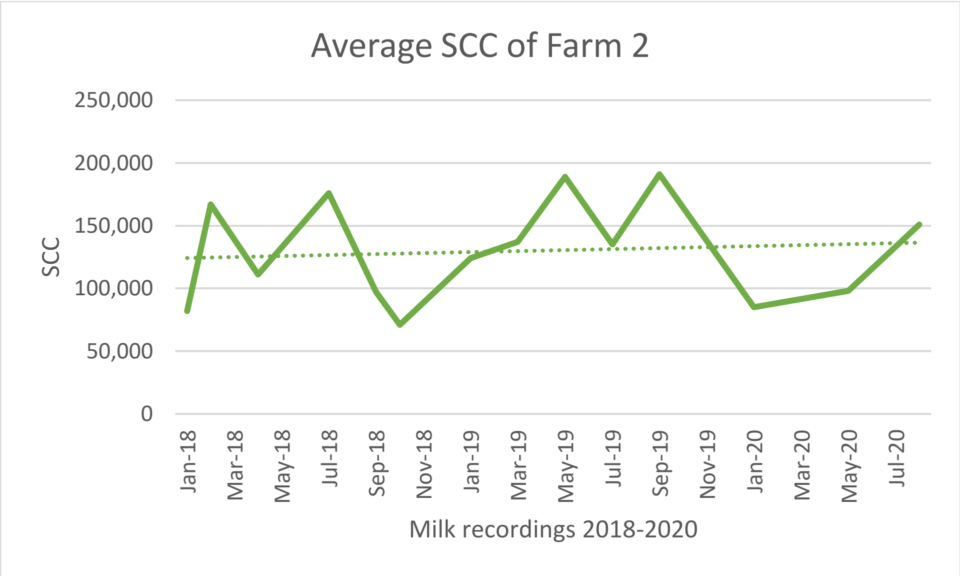


Diagram 15: The average SCC on farm 2.

Diagram 15 exhibits a slight increasing trend seen among the SCC average of the herd. Attempting to find a trend was made more difficult due to the lack of recordings carried out. However, it is important to note that the average SCC of the herd never exceeded 200,000 cells/ml which is the target set by "CellCheck".

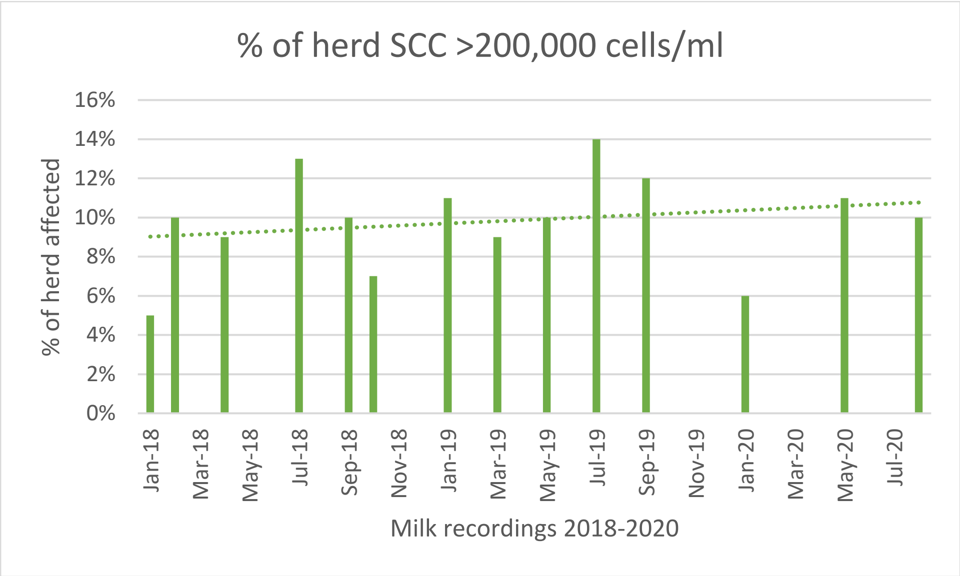


Diagram 16: The percentage of the herd with an SCC >200,000 cells/ml on farm 2.

From diagram 16, there is slight increasing trend seen when examining the percentage of the herd that had an SCC >200,000 cells/ml. However, it is again important to note that the herd always remained below the 15% target set by "CellCheck".

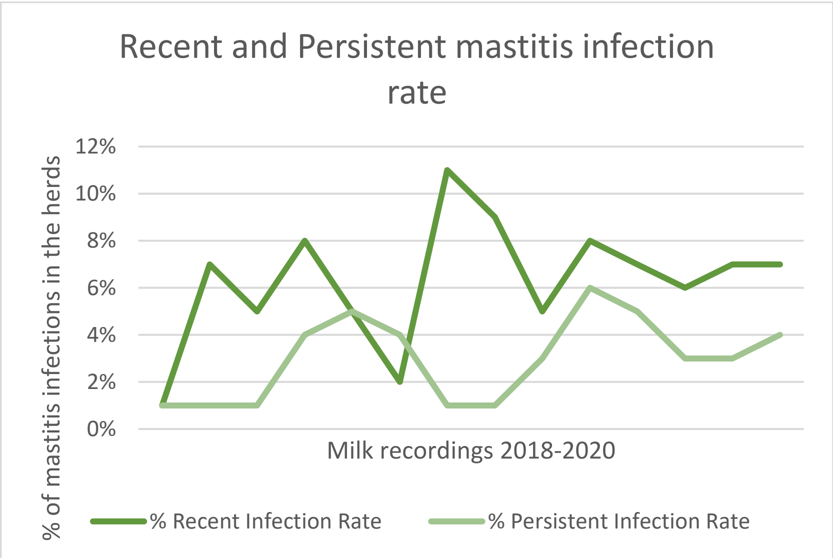


Diagram 17: The recent and persistent mastitis infections on farm 2.

The percentage of the herd with recent mastitis infection rates has shown to be slowly increasing by diagram 17. This may indicate that the hygiene during lactation, particularly at milking, may have been inadequate. The percentage of the herd suffering from persistent mastitis infection has also slowly risen since the beginning of milk recording. This shows that a percentage of cows have an SCC >200,000 cells/ml in the last two milk recordings of the current lactation. However, the herd has remained below the target of 6% set by "CellCheck".

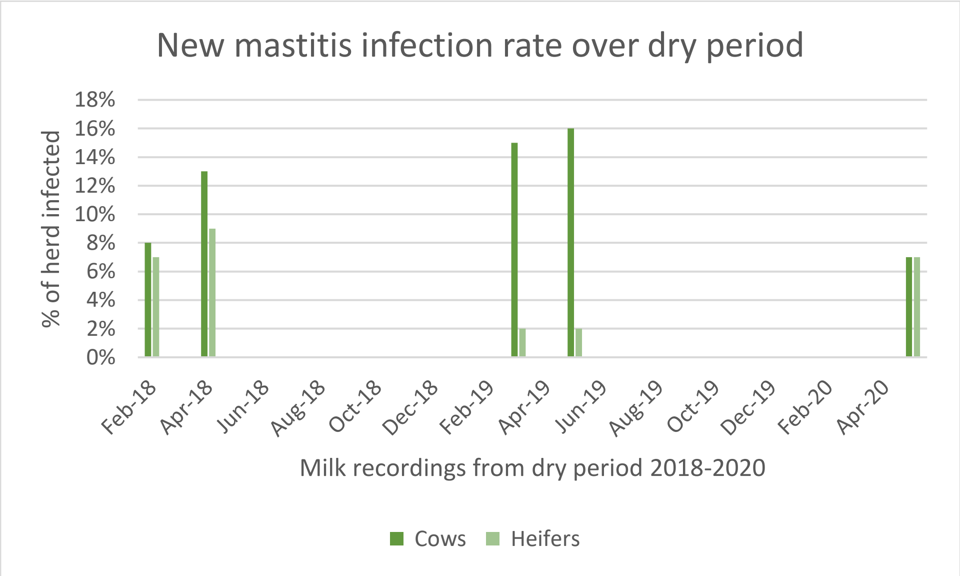


Diagram 18: The new mastitis infection rate over the dry period on farm 2.

In diagram 18, the rate of new mastitis infections in cows was showing to have an increasing trend throughout initially, however, it has shown a rapid decline since January 2020. This may indicate that the cause of the increasing infection was dealt with by the farmer or that farm hygiene has been improved. The rate of new mastitis infections in heifers has been less consistent.

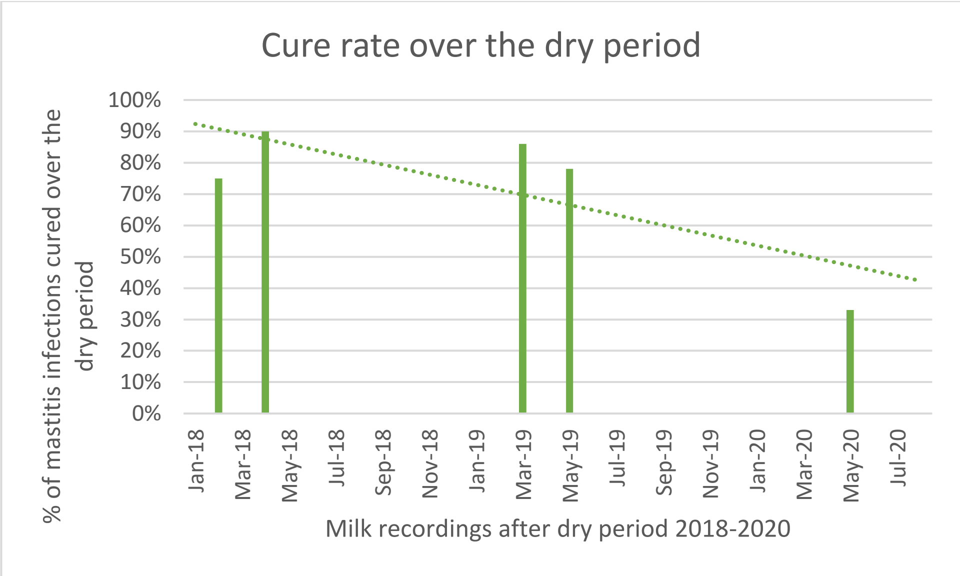


Diagram 19: The cure rate of mastitis cases over the dry period on farm 2.

In diagram 19, the cure rate over the dry period has shown a significant deterioration since introducing SDCT. In the milk recordings carried out in 2020, it is important to note that the number of cows to be cured ranged from 1-3 animals. Due to complications caused by COVID-19, this farmer was unable to perform milk recordings during the lactation period in 2020 any earlier than May of 2020. This makes it difficult to draw a decisive conclusion as to the effects of SDCT on the cure rate of the herd. Furthermore, the majority of recordings were below the target of 85%.

This farm had not recorded those animals that had received teat sealant alone and those that received intramammary antibiotic and a teat sealant at drying off. Therefore, I was unable to track cows that had cases of CM within the first 100 DIM.

5.3. Farm 3

Farm 3 analysis is summarised as follows in table 6,

	2019	2020
No. of animals recorded	68	59
Average SCC	214,000 cells/ml	186,000 cells/ml
% of herd >200,000 cells/ml	9% (6 animals)	19% (11 animals)
Recent infection rate	0%	13%
Persistent mastitis infection rate	0%	8%
New infection rate over the dry period	Cows – 20% Heifers – 17%	Cows – 6% Heifers – 0%
Cure rate over the dry period	100%	100%
Avoidable milk loss	13.7L/Herd/day	28.5L/Herd/day

Table 5: A summary of the findings on farm 3.

In 2019, 6 animals had an SCC >200,000 cells/ml. 1 animal was in their 1st lactation, 3 animals were in their 2nd lactation. The other 2 animals were in their 3rd lactation or above.

In 2020, 11 animals had an SCC >200,000 cells/ml. 1 animal was in their 1st lactation, 5 animals were in their 2nd lactation. The remaining 5 animals were in their 3rd lactation or above.

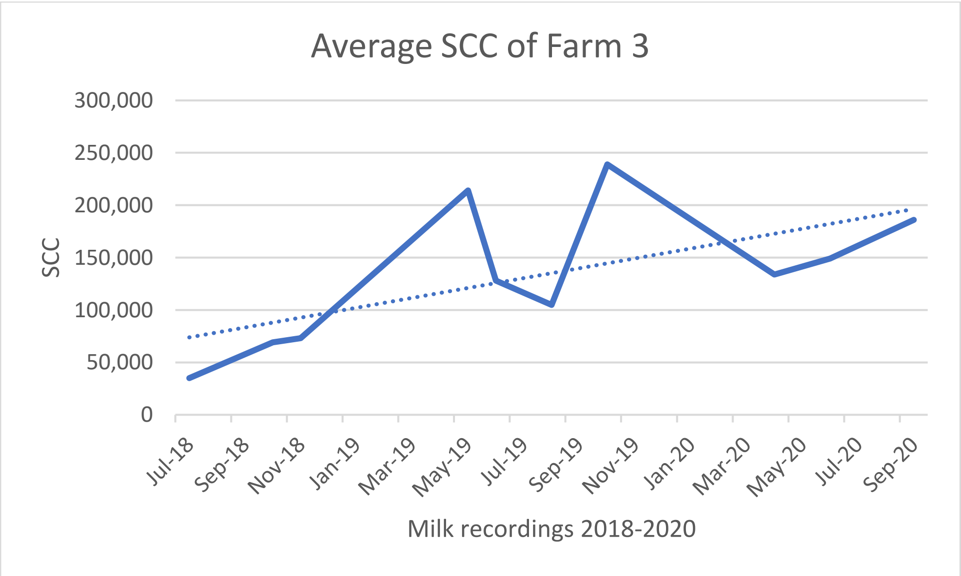


Diagram 20: The average SCC of the herd on farm 3.

From diagram 20, there is clear increasing trend in the herds average SCC. There were two peaks reaching over 200,000 cells/ml, occurring in May 2019 when the SCC reached

214,000 cells/ml and in October 2019 reaching 239,000 cells/ml. In May 2019, only 9% of the herd had an individual SCC >200,000 cells/ml which suggests that a smaller proportion of animals had an SCC that was far greater than 200,000 cells/ml leading to the increase. However, in October 2019, 30% of the herd had an SCC >200,000 cells/ml suggesting that a much higher proportion of animals had an increased SCC.

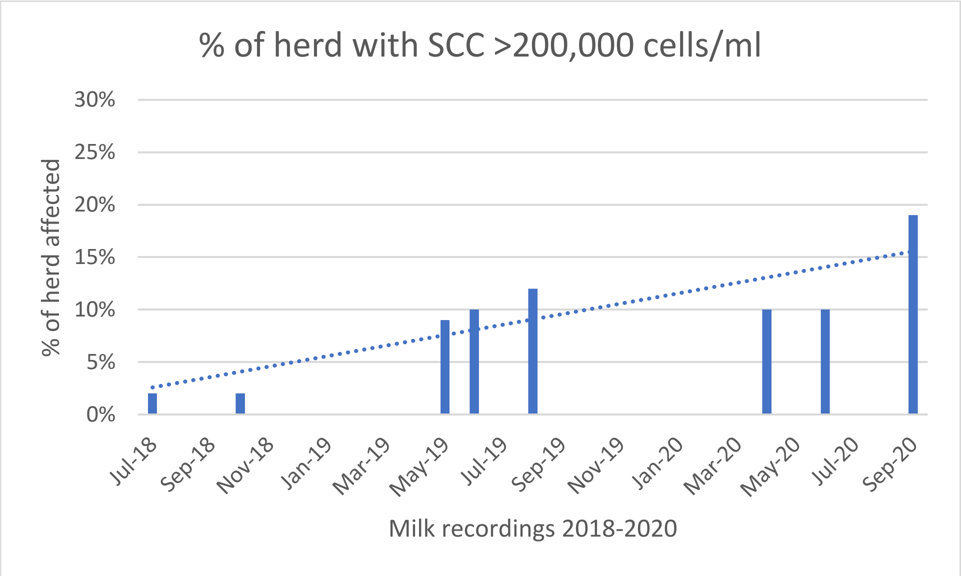


Diagram 21: The percentage of the herd with a SCC >200,00 cells/ml on farm 3.

As shown in diagram 21, there has been a significant level of growth seen in the percentage of the herd whose SCC is >200,000 cells/ml.

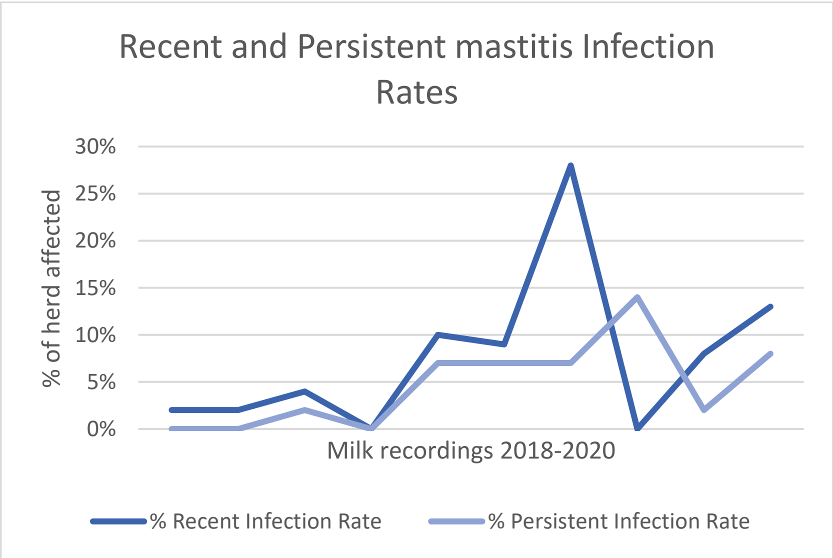


Diagram 22: The recent and persistent infection rates on farm 3.

As depicted in diagram 22, when viewing the percentage of the herd with recent mastitis infections, there is a definitive increase being seen. There was a large surge seen in October 2019, corresponding to the large increase the herds average SCC. This was due to problems in the milking parlour as there was relief milkers carrying out the milking due to the farmer taking holidays. As a result of this, there couldn't have been a guarantee of a consistently good milking procedure. As well as this, at this time there was a change in weather resulting in heavier rainfall. As this herd is a grazing herd, this meant that maintenance of cleanliness at pasture and on the pathways leading to and from the milking parlour was made more difficult. However, it is evident that in the following milk recording that this outbreak of mastitis was dealt with in early 2020. When examining the rate of persistent mastitis infections, its trend was very similar to that of the recent infections. There is a clear increase being seen from July 2018 – September 2020, with a surge seen in April 2020 to 14% which is nearly double the target set at 8%.

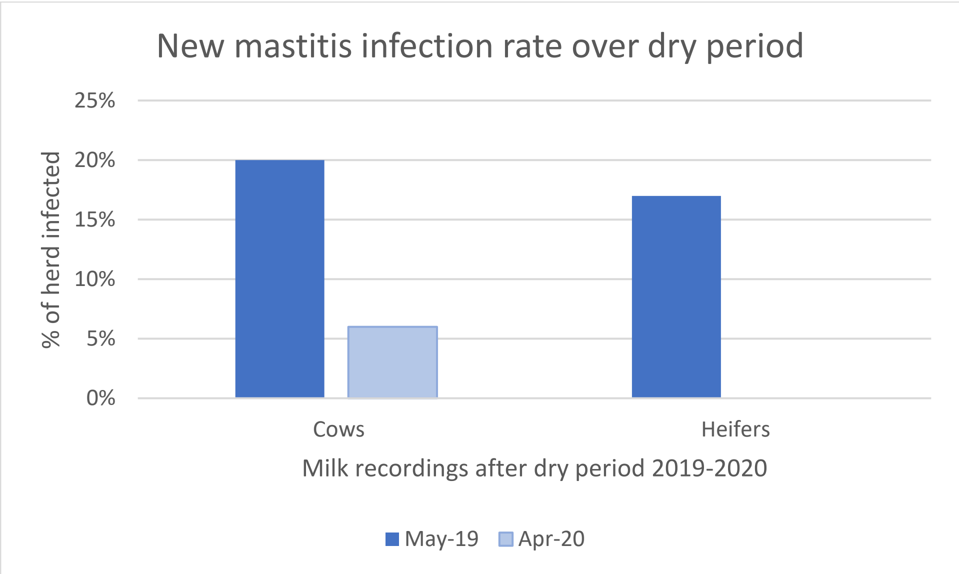


Diagram 23: The new mastitis infection rate over the dry period on farm 3.

In diagram 23, the new mastitis rates in cows occurring over the dry period suggests that there is an increasing progression being seen. 2019 milk recordings showed marked increase of up to 20-25%, which is double the 10% target set by "CellCheck". Moreover, it is important to take into account that the lack of milk recordings performed by the farmer in the early lactation of 2019 makes it difficult to conclude if SDCT may have influenced this outcome. Furthermore, in 2020 this rate of new mastitis infection in cows over the dry period has been sustained at 6% since April 2020. In diagram 23, since April 2020 the rate of new infection over the dry period in heifers has remained at a persistent 0%.

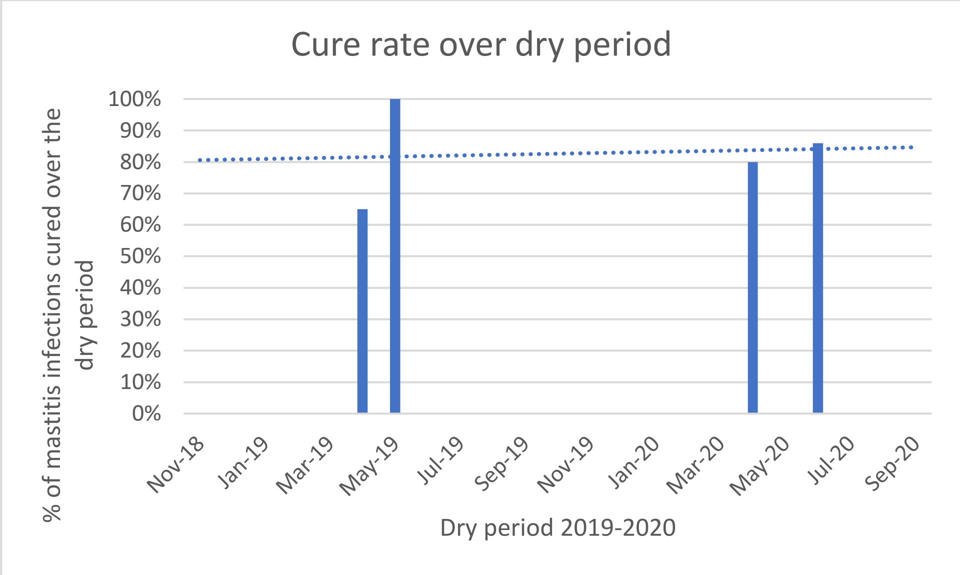


Diagram 24: The cure rate of mastitis cases over the dry period on farm 3.

In diagram 24, the cure rate over the dry period shows a slight improvement since the introduction of SDCT.

5.4. Farm 4

Farm 4 analysis is summarised as follows in table 7,

	2019	2020
No. of animals recorded	36	51
Average SCC	69,000 cells/ml	71,000 cells/ml
% of herd >200,000 cells/ml	8% (3 animals)	6% (3 animals)
Recent infection rate	7%	5%
Persistent mastitis infection rate	3%	0%
New infection rate over the dry period	Cows – 7% Heifers – 17%	Cows – 4% Heifers – 0%
Cure rate over the dry period	50%	100%
Avoidable milk loss	10.8L/Herd/day	6.4L/Herd/day

Table 6: A summary of the findings on farm 4.

In 2019, 3 animals had an SCC >200,000 cells/ml. All of these animals were in their 3rd lactation or above.

In 2020, 3 animals had an SCC >200,000 cells/ml. 1 animal was in their 1st lactation, 1 animal was in their 2nd lactation and 1 animal was in its 3rd lactation or above.

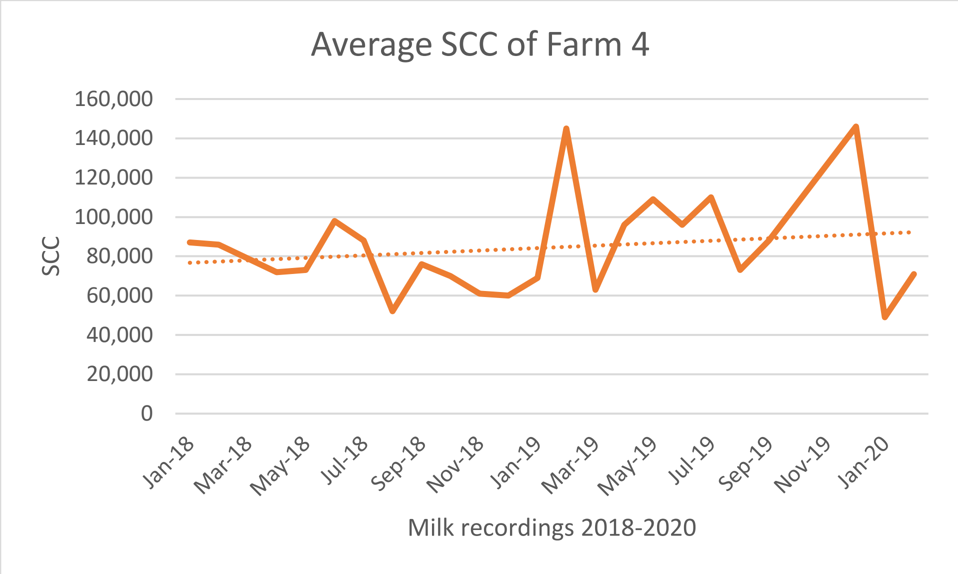


Diagram 25: The average SCC of the herd on farm 4.

In diagram 25, there is a slight increasing trend in the herds average SCC being exhibited. In addition, the herd has stayed below the 200,000 cells/ml threshold.

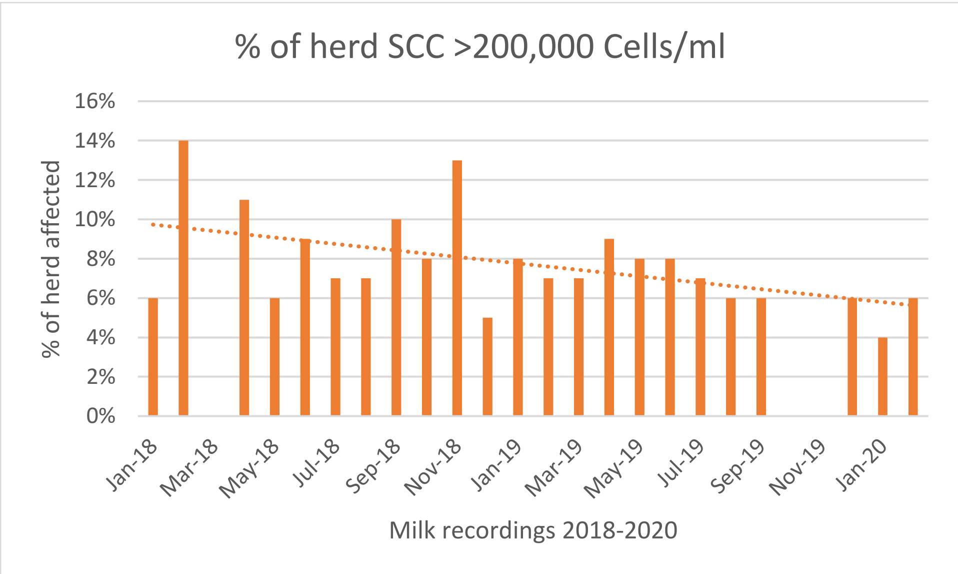


Diagram 26: The percentage of the herd with an SCC >200,000 cells/ml on farm 4.

From diagram 26, there is a decrease being seen in the % of the herd whose SCC is >200,000 cells/ml, particularly since 2019 when SDCT was introduced.

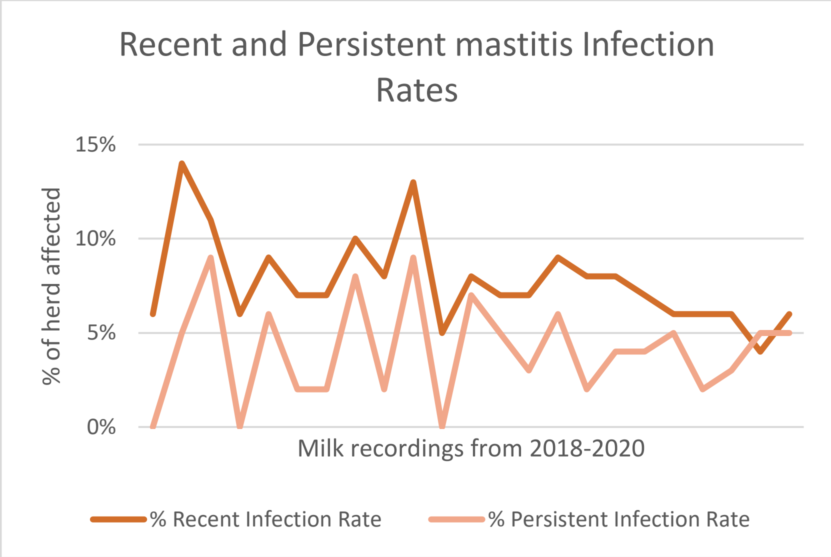


Diagram 27: The recent and persistent mastitis infections on farm 4.

In diagram 27, the percentage of recent mastitis infection rates has shown that there is a decreasing trend being seen. With a target of 7%, there were a total of 10 out of 23 recordings that were over this target. The percentage of the herd with persistent infections has also failed to present any consistent trend.

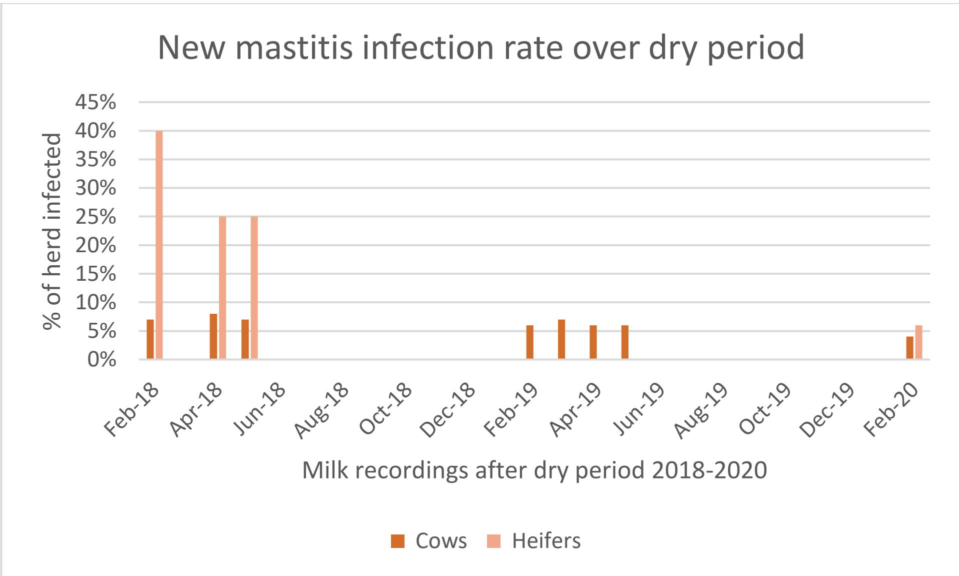


Diagram 28: The new mastitis infection rate over the dry period on farm 4.

In diagram 28, the rate of new mastitis infection occurring over the dry period in cows has seen a steady decrease since the beginning of 2018. In August 2019, the rate reached 4% and has reached levels as low as 0% in the beginning of 2020. The target rate for cows has never exceeded 8%. The rate of new mastitis infection occurring over the dry period in heifers, however, had large increases in 2018 with milk recordings in February 2018 reaching 40%. These levels remained high, fluctuating between 29-17% until February 2019 where a sharp decrease to 0% was observed. These high rates may have been linked to poor hygiene at drying off or high incidences of environmental mastitis pathogens being present that proved difficult to eradicate. Since February 2019, milk recordings have shown rates of new mastitis infections over the dry period in heifers as 0% with the latest recording showing a rate of 6%.

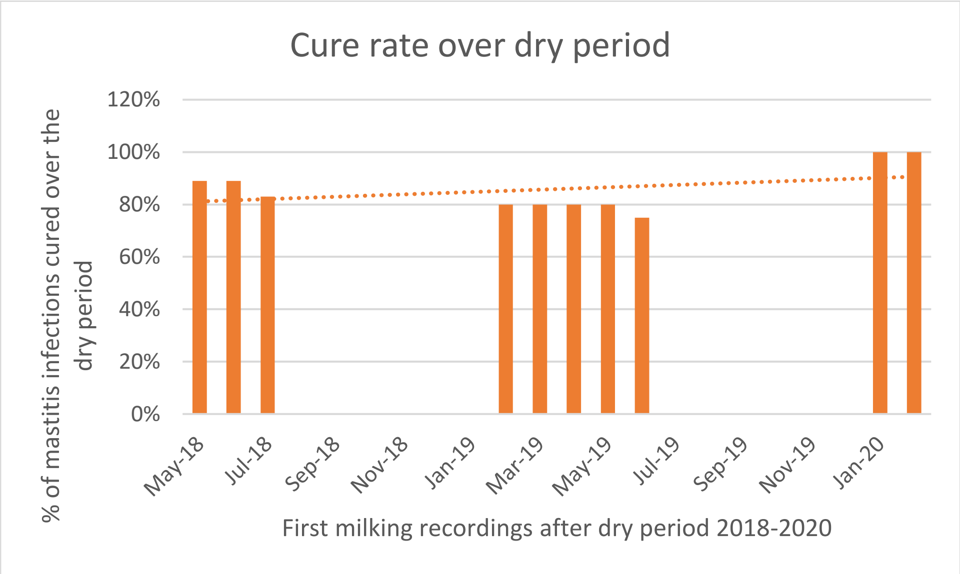


Diagram 29: The cure rate of mastitis cases over the dry period on farm 4.

In diagram 29, the cure rate for mastitis over the dry period shows there is a slight improvement since the introduction of SDCT in 2019.

6. Discussion

On farm 1, the method of selection for SDCT utilised the SCC obtained from the milk recordings. This farmer set a threshold of 50,000 cells/ml, resulting in any animal that had a SCC above this in the milk recording prior to drying off being given an intramammary antibiotic and a teat sealant during the drying off process. SCC as a selection method has been the main focus in many studies previously (Scherpenzeel et al., 2014, Scherpenzeel et al., 2016, Scherpenzeel et al., 2018, Zecconi et al., 2018). Although some studies combined the SCC of individual animals and the parity for the selection of animals (Scherpenzeel et al., 2016, Scherpenzeel et al., 2018 and Zecconi et al., 2018), sufficient data for selection can be gathered by using the SCC alone. With the 50,000 cells/ml being set for all animals regardless of parity in this herd, this is somewhat contradictory to that of (Zecconi et al.,

2018) where it was suggested a threshold of 100,000 cells/ml for primiparous cows and 200,000 cells/ml for multiparous cows were the ideal thresholds. Although it was found that primiparous cows had consistently low SCC in milk recordings with a threshold of 50,000 cells/ml in that particular study. In relation to farm 1, the farmer commented that there was a lower risk with a threshold of 50,000 cells/ml as this helps eliminate those cows that may be considered acceptable at higher thresholds as it increases the sensitivity of his selection criteria to ensure infected cows receive antibiotic treatment. For example, if a cow had 3 quarters with an SCC of 30,000 cells/ml and 1 infected quarter with an SCC of 650,000 cells/ml, her average SCC would be 185,000 cells/ml.

Prior to drying off, random milk samples were taken from a group of cows and a sample was also taken from the bulk tank for culture. In terms of dry period length, farm 1 set the dry period of primiparous cows at 90 days and for multiparous cows at 90-60 days depending on aspects such as BCS or whether they had had a case of mastitis during that lactation. Studies have shown that dry periods >30 days result in an increase in milk production (Cameron et al., 2015). The dry period length set on farm 1 also conforms with (Robert A. et al., 2008), who found that in untreated animals, those who had a dry period of >60 days had lower levels of new intramammary infection rates developing during the dry period. When examining the post-calving intramammary infection rate, (Cameron et al., 2013) documented that the difference of intramammary infection rates between the BDCT and SDCT groups. On farm 1, the post calving intramammary infection rate in 2019 was 8.5% and in 2020 it was 7.3%. Similar to what has been reported by (Cameron et al., 2013), who found that SDCT groups had a post-calving intramammary infection rate of 10.6%. It was also noted that there was no significant increase in risk of CM cases occurring in those animals that received only a teat sealant. This corresponds with the data collected on farm 1 during this study, showing that 38.46% of CM cases had received a teat sealant only in 2019 and 43.5% in 2020. On farm 1, teat sealant was given to all animals, regardless of whether they were to receive intramammary antibiotics or not. Although a teat sealant isn’t deemed as a requirement of SDCT, there are several studies that suggest that adding some form of protection in those that will not receive intramammary antibiotics helps prevent bacteria invading the udder (Cameron et al., 2015, Kennedy et al., 2017 and Mütze K. et al., 2012). (Mütze K. et al., 2012) documented that those who received only an intramammary antibiotic had a higher infection rate of *Corynebacterium spp.* (Winder CB et al., 2017) found that there was an impressive difference in the frequency of intramammary infections post-calving in SDCT groups that received no teat sealant. This would support the use of teat sealant in all cows at drying off to help prevent increases in intramammary infections prior to calving. (Kennedy et al., 2017) found that in those animals that received a teat sealant only, they had an average SCC of 70,374 cells/ml after calving. However, on farm 1 the average SCC of the cows that received only a teat sealant was 151,375 cells/ml. In addition, it is important to note that 2 cows may be considered outliers with SCC of 5,923,000 cells/ml and 2,164,000 cells/ml which could cause these results to become skewed. These may have been clinical cases. If these two cows were excluded, the average SCC after calving of those having received only a teat sealant would be 40,171 cells/ml.

(Kennedy et al., 2017) reported that >80% of the herds maintained an SCC of <200,000 cells/ml in both the group that received a teat sealant alone and the group the received an intramammary antibiotic and a teat sealant. This correlates with the data collected from the farms, showing that on farm 1 90-94.1% of the herd had an SCC <200,000 cells/ml from 2018-2020 as seen in diagram 11, farm 2 89-95.4% of the herd had an SCC <200,000 cells/ml as shown in diagram 15, farm 3 81-98% of the herd had an SCC <200,000 cells/ml as seen in diagram 20 and on farm 4 92-94% of the herd had an SCC of <200,000 cells/ml as seen in diagram 25. On farm 1, in 2019 there were 37 quarter cases of CM in 25 animals, 26 of these cases were in animals that had been treated with an intramammary antibiotic and a teat sealant. The remaining 11 cases came from animals that received the teat sealant alone. In 2020, there were 25 quarter cases in 23 animals, 14 of these cases were in animals that had been treated with an intramammary antibiotic and a teat sealant. While the remaining 11 cases were in animals only given a teat sealant. (Berry & Hillerton, 2002) found that when investigating the risk of SDCT with new intramammary infection and CM cases after calving there were higher proportions of CM cases occurring in cows who had been untreated. Of the 77 cases that occurred in the commercial herds, 75.3% occurred in the untreated cows. However, from the data collected in this study it was found that there were higher proportions of cows with CM cases after caving from the treated groups. In 2019, of the 37 quarter cases of CM, 26 quarters were in cows that had been treated which was 70.3% of the total CM cases after calving. This strongly contradicts the findings of (Berry & Hillerton, 2002). In 2020, of the 25 quarter cases of CM that occurred on farm 1, 14 occurred in those that had been treated at drying off which is 56% of total CM cases after calving. In this study, practices on farm 1 such keeping dried off cows at pasture for the first 2 weeks of the dry period was attributed to the low levels of CM cases after calving, as well as daily cleaning and disinfecting of the cubicle with lime twice daily. This is corroborated by (Green MJ. et al., 2007) who found there was higher incidence of CM cases in animals that were housed for the dry period than those kept as pasture for the entire duration of the dry period. General hygiene aspects also were linked to the lower incidence of CM cases. When examining the influence of parity and its association with the increase in CM incidence. On farm 1, farm 2, farm 3 and farm 4 there was on average 74%, 62%, 44% and 77.77% of animals with CM cases over the 3 years were in their 3rd lactation or above, respectively. This data collected is aided by literature claiming that cows in their 3rd lactation or above have a higher risk of being affected by new intramammary infections (Cameron et al., 2013). It was also stated by (Mütze K. et al., 2012) and (Green MJ. et al., 2007) that there were heighten risks of issues surrounding udder health and CM in older cows.

In 2019 on farm 1, 23.68% of the herd received no intramammary antibiotic. The remaining 76.32% required antibiotic treatment at drying off. In 2020 on Farm 1, they had planned to dry off 42.9% of the herd with a teat sealant alone. The remaining 57.1% of the herd were to receive an intramammary antibiotic and a teat sealant. *Cepravin DC* and *Bovaclox DC* are the products used. The active ingredient in *Cepravin DC* is Cephalonium which is a 1st generation cephalosporin, this is considered a HIA. This was given to cows who had SCC >200,000 cells/ml or cows who were suffering from mastitis at drying off. The active ingredients of *Bovaclox DC* are Cloxacillin, which is considered a HIA and ampicillin, which is considered one of the HP CIA. On farm 1, *Bovaclox DC* was administered to those cows who has an SCC of 51,000-200,000 cells/ml or cows who had had a case of mastitis earlier in the year. In 2019, 232/304 animals were dried off with antimicrobials. 6.5% of these animals were given a CIA and the remaining 93.5% of these animals were treated using one of the HP CIA. These figures show that on the farm the vast majority of animals are receiving HP CIA at drying off which is concerning. These correlate with (More et al., 2017), who found that in Ireland there was an increase from 794 – 1,022 DCDvet per 1000 animals per year in the number of DCT sold that contained HP CIA. However, it was also reported in this study that there was a large increase in the sale of teat sealant, showing that there was increase in ~ 211,000 teat sealant tubes per year. On farm 1, in 2019 there were 37 quarter cases of CM in the first 100 DIM. These were treated with *Synulox* and *Terrexine* lactating cow tubes. The active ingredients in *Synulox* are amoxicillin and clavulanic acid and in *Terrexine* the active ingredients are kanamycin and cefalexin. Amoxicillin, Kanamycin and cefalexin are antimicrobials that are classed as HP CIA by the WHO. In 2020 however, there was a decrease in 32.4% of the number of quarter cases of CM in the first 100 DIM. Overall, resulting in a decrease in the number of cows being administered lactating cow treatment containing HP CIA. (More et al., 2017) also recorded decreases in the number of lactating cow tubes being sold by ~ 663-466 annually. However, increases were recorded in the number of lactating tubes being sold containing HP CIA in this study also.

Prior to drying off, farm 1 randomly sampled a group of cows for milk culture. The bulk tank was also sampled for culture purposes. The results found that *Streptococcus uberis* was the main pathogen found both in individual cows and in the bulk tank. There were small amounts of *E. coli* also present. Although not every animal had a milk culture performed, (Cameron et al., 2015) suggests that the on-farm culture could further the accuracy of SDCT implementation. In terms of antibiotic resistance, these pathogens were found to be resistance to aminoglycosides, in particular neomycin. These findings conform with that found by (Garch et al., 2020), where it was reported that *Staphylococcus aureus, E. coli* and *Streptococcus uberis* were the 3 most common mastitis pathogens found from milk cultures. It was also detailed that 4% of E. coli strains are resistant through being encoded with *ESBL/AmpC* genes. (Garch et al., 2007) cited there were increases in resistance rates among mastitis pathogens from 2009-2012, the antimicrobial resistance found on farm 1 suggests that there are growing levels of resistance. (Boireau et al., 2018) reported that there are rising levels of resistance with *Streptococcus uberis* against all antimicrobials. However, *E. coli's* resistance remained stationary over a 10 year against amoxicillin. As amoxicillin is one of the main ingredients in *Synulox* for treating mastitis cases, some positive can be drawn from the study.

I interviewed the farmers in order to discover as to why they first sought to implement SDCT within their herd. The most common reasons were due to legislative change, for better treatment response in cows with CM cases in the following lactation, to cut down on cost and to decrease the risk of antibiotic contamination of the bulk tank. With the legislative change that is due to come into place by January 2022 in Ireland, the farmers felt it "is better to get ahead of the game", rather than being "backed into a corner" in the future. One farmer mentioned that he did not see the benefit in "giving an antibiotic to a cow who doesn't have anything to cure". (Scherpenzeel et al., 2016) found a similar mindset in farmers in the Netherlands who believed the main advantages of SDCT were decreasing antibiotic usage and the financial benefits that accompanied that. It was also found that 87% of farmers believed they "could still be good farmers without antibiotic overreliance". When asked about apprehensions farmer had when starting SDCT, the most common reasons I found were the risk of losing quarters during the dry period and also the increase in CM infections. This again agrees with the findings of (Scherpenzeel et al., 2016) who found that in the Netherlands farmers main concern was the risk of having a higher number of sick cows. Since the implementation of SDCT on the farms examined, the progress shown on the farms has been varied. With farm 1, the average SCC on farm has decreased by 44.25% from 174,000-97,000 cells/ml from 2018-2020. Farm 4 has also seen positive impact, with the average SCC on farm decreasing by 18.4% from 87,000-71,000cells/ml from 2018-2020. However, farm 2 and 3 have not had as conclusive results. On farm 2 there has been an increase of the average SCC of 84% from 82,000-151,000 cells/ml, while on farm 3 there has been an increase of 430% from 35,000-186,000 cells/ml 2018-2020. These increase in the average SCC may be due to improper hygiene particularly during the drying off process, improper hygiene surrounding housing and bedding or it may be that their selection method for cows does not suit their farm. Nonetheless, there are some positives to be drawn from the data. The new infection rate on farm 1 showed an average of 8% in cows and 4% in heifers from 2018-2020. Farm 2 had an average of 8.3% in cows and 1% in heifers. Farm 3 had an average of 8.6% in cows and 5.67% in heifers. Farm 4 had an average of 6.3% in cows and 7.6% in heifers. The average persistent infection rate from 2018-2020 on farms 1-4 ranged from 2-3%. However, I do feel that it is important to note that with having access on just one farm to all the necessary data regarding the breakdown of each herd with the number receiving antimicrobials and a teat sealant or a teat sealant alone and the figures surrounding CM cases in the following lactation, it is difficult to fully gauge the outcome of SDCT on the farms. The new mastitis infection rate over the dry period resulted in impressive improvements on farm 1, 3 and 4, as seen in diagrams 13, 18 and 28 respectively. On farm 1, the new infection rate over the dry period for heifers dropped from 10% in 2019 to 0% in 2020. For cows, there was a new infection rate in 2019 of 10% and in 2020 there was a new infection rate of 8%, showing slight improvement. On farm 3, the new infection rate over the dry period in cows decreased from 20% in 2019 to 6% in 2020. There was also an improvement seen in the heifers with a new infection rate of 17% in 2019 to 0% in 2020. On farm 4, the new infection rate improved hugely in the heifers, with a decrease from 40% infection rate to 6% in 2020. Cows showed a small improvement from 7% to 4% in 2020. For farm 2, there was no change overall, however there was an increase seen in the new infection rate in cows following 2019 calving with 15-16% infection rate. In 2020, this subsequently decreased to 7%. The cure rate over the dry period on the four farms also resulted in varied results. On farm 1, there was a decrease from 90% to 50% as seen in diagram 14 and on farm 2 there was a decrease to 33% cure rate over the most recent dry period, as seen in diagram 19. This deterioration may have been due to the dry period being introduced; further studies may need to be done to further explore this. Moreover, on farm 3 and 4 there were positive trends seen in their cure rate over the dry period with improvements being shown, as shown in diagrams 24 and 29, respectively.

There were data limitations throughout this study which may impact the conclusions. The lack of consistency in milk recordings by farmers made it difficult to find conclusive results particularly with information surrounding the cure rate over the dry period, the new mastitis infections that occurred over the dry period and CM and SCM cases that occurred within the first 100 DIM. In 2020, farmers did not engage in the early part of the year as they have previously done due to the COVID-19 pandemic restrictions preventing the milk recording personnel from entering the farms. Along with this, there was insufficient data recorded by 3 of the 4 farms surrounding those animals that had been dried off with teat sealant alone and those that had been dried off with an intramammary antibiotic and a teat sealant. As a result of this, I was unable to track cows in the following lactation and track those cows that suffered with a case of CM.

7. Conclusion

The use of SDCT on dairy farms in Ireland has shown to have varied results. From this study, there was only one farm that showed decisive results that the SDCT had benefited the farm. The selection method of cows by farmers for SDCT may require more attention and farmers may call for further knowledge on the matter in order to fully succeed with the method. In terms of antimicrobial usage, there was shown to be some reduction of usage on farms but, again, the repercussions of poor selection protocol and adherence to hygiene measures at drying off make the reduction of antimicrobial usage challenging. The focus on hygienic conditions, particularly surrounding the drying off process, is paramount when using SDCT and this may be an area to perfect prior to implementing SDCT. There are obvious economic benefits shown with the implementation of SDCT, particularly on the cost of antimicrobials at drying off and in the following lactation. In future, I feel it would be more beneficial to have a larger group of farms to analyse, with access to all the necessary data including CM cases of all farms and figures pertaining to those animals dried off with or without antimicrobials.

8. Summary

The purpose of this thesis is to focus on the use of selective antibiotic dry cow therapy on dairy farms in Ireland during the dry period, assess its role in the reduction of antimicrobial use and its animal health, milk quality and economic effects. I examined 4 farms, who have all been implementing SDCT since 2019, with the aim of discovering whether they improved or disimproved since its introduction. Using reports from Animal Health Ireland "CellCheck", I gathered the information surrounding average SCC of the herds, the recent and persistent mastitis infection rates during lactation and occurrences over the dry period and also the cure rate of mastitis cases over the dry period. One farm was used to examine to the cost of drying off the herd and the cost of treating cases of clinical mastitis in the following lactation. In addition to using the CellCheck reports, phone interviews were carried out with farmers to discover as to why they introduced SDCT to their herd and what apprehensions they had surrounding the subjects. From this study, only 1 farm out of 4, showed a definitive improvement in their average SCC in the herd. The other 3 farms did, in fact, disimprove in their average SCC. 3 out of 4 farms showed improvement recent and persistent mastitis infection rates.

9. Bibliography

Berry, E. and Hillerton, J., 2002. The Effect of Selective Dry Cow Treatment on New Intramammary Infections. *Journal of Dairy Science*, 85(1), pp.112-121. https://doi.org/10.3168/jds.S0022-0302(02)74059-9

Boireau, C., Cazeau, G., Jarrige, N., Calavas, D., Madec, J., Leblond, A., Haenni, M. and Gay, É., 2018. Antimicrobial resistance in bacteria isolated from mastitis in dairy cattle in France. *Journal of Dairy Science,* [online] 101(10), pp.P9451-9462. Available at: https://www.journalofdairyscience.org/article/S0022-0302(18)30734-3/abstract. https://doi.org/10.3168/jds.2018-14835

Botrel, M.A., Haenni, M., Morignat, E., Sulpice, P., Madec, J.Y. and Calavas, D., 2010. Distribution and antimicrobial resistance of clinical and subclinical mastitis pathogens in dairy cows in Rhône-Alpes, France. *Foodborne pathogens and disease*, *7*(5), pp.479-487. https://doi.org/10.1089/fpd.2009.0425

Cameron, M., Keefe, G., Roy, J., Stryhn, H., Dohoo, I. and McKenna, S., 2015. Evaluation of selective dry cow treatment following on-farm culture: Milk yield and somatic cell count in the subsequent lactation. *Journal of Dairy Science*, 98(4), pp.2427-2436. https://doi.org/10.3168/jds.2014-8876

Cameron, M., McKenna, S., MacDonald, K., Dohoo, I., Roy, J. and Keefe, G., 2014. Evaluation of selective dry cow treatment following on-farm culture: Risk of post calving intramammary infection and clinical mastitis in the subsequent lactation. *Journal of Dairy Science,* 97(1), pp.270-284. https://doi.org/10.3168/jds.2013-7060

CDC. Antibiotic Resistance Threats in the United States, 2019. Atlanta, GA: U.S. Department of Health and Human Services, CDC; 2019. URL:https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf [Accessed: 5 October 2020]

El Garch, F., Youala, M., Simjee, S., Moyaert, H., Klee, R., Truszkowska, B., Rose, M., Hocquet, D., Valot, B., Morrissey, I. and de Jong, A., 2020. Antimicrobial susceptibility of nine udder pathogens recovered from bovine clinical mastitis milk in Europe 2015–2016: VetPath results. *Veterinary Microbiology*, 245, p.108644. https://doi.org/10.1016/j.vetmic.2020.108644

Firth, C.L., Käsbohrer, A., Egger-Danner, C., Fuchs, K., Pinior, B., Roch, F.F. and Obritzhauser, W., 2019. Comparison of defined course doses (DCDvet) for blanket and selective antimicrobial dry cow therapy on conventional and organic farms. *Animals*, *9*(10), p.707. https://doi.org/10.3390/ani9100707

Green, M.J., Bradley, A.J., Medley, G.F. and Browne, W.J., 2007. Cow, farm, and management factors during the dry period that determine the rate of clinical mastitis after calving. *Journal of dairy science*, *90*(8), pp.3764-3776. https://doi.org/10.3168/jds.2007-0107

Huijps, K., Lam, T.J. and Hogeveen, H., 2008. Costs of mastitis: facts and perception. *Journal of Dairy Research*, *75*(1), p.113.

International Coordination Group on Antimicrobial Resistance (IACG), 2019, No Time to Wait: Securing the future from drug-resistant infections. [PDF] URL:https://www.who.int/antimicrobial-resistance/interagency-coordination-group/IACG_final_report_EN.pdf?ua=1, [Accessed: 5 November 2020]

Kennedy, A., McParland, S., Flynn, J., Byrne, N., Coughlan, F., Murphy, J., Leane, S. and Ryan, N., 2020. *Selective Dry Cow Therapy*. [ebook] Teagasc Ireland, pp.7-16. Available at: <https://www.teagasc.ie/media/website/publications/2017/NDC_Aideen-Kennedy.pdf> [Accessed 1 October 2020].

More, S., Clegg, T. and McCoy, F., 2017. The use of national-level data to describe trends in intramammary antimicrobial usage on Irish dairy farms from 2003 to 2015. *Journal of Dairy Science,* 100(8), pp.6400-6413. https://doi.org/ 10.3168/jds.2016-12068

Mütze, K., Wolter, W., Failing, K., Kloppert, B., Bernhardt, H. and Zschöck, M., 2012. The effect of dry cow antibiotic with and without an internal teat sealant on udder health during the first 100 d of lactation: a field study with matched pairs. *The Journal of dairy research*, *79*(4), p.477. https://doi:10.1017/S0022029912000477

Nobrega, D., De Buck, J. and Barkema, H., 2018. Antimicrobial resistance in non-aureus staphylococci isolated from milk is associated with systemic but not intramammary administration of antimicrobials in dairy cattle. *Journal of Dairy Science*, 101(8), pp.7425-7436. https://doi.org/10.3168/jds.2018-14540

O'Neill, J. 2016. Tackling Drug-resistant Infections Globally: Final Report and Recommendations–The Review on Antimicrobial Resistance Chaired by Jim O'Neill. Wellcome Trust HM Gov. London. [PDF.] URL: https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf. [Accessed: 12 November 2020]

Pérez, V.K.C., da Costa, G.M., Guimarães, A.S., Heinemann, M.B., Lage, A.P. and Dorneles, E.M.S., 2020. Relationship between virulence factors and antimicrobial resistance in Staphylococcus aureus from bovine mastitis. *Journal of Global Antimicrobial Resistance*. https://doi.org/10.1016/j.jgar.2020.06.010

Robert, A., Roussel, P., Bareille, N., Ribaud, D., Sérieys, F., Heuchel, V. and Seegers, H., 2008. Risk factors for new intramammary infections during the dry period in untreated dairy cows from herds using selective dry cow therapy. *Animal: an international journal of animal bioscience*, *2*(2), p.247. https://doi: 10.1017/S1751731107000833

Scherpenzeel, C.G.M., Den Uijl, I.E.M., van Schaik, G., Riekerink, R.O., Keurentjes, J.M. and Lam, T.J.G.M., 2014. Evaluation of the use of dry cow antibiotics in low somatic cell count cows. *Journal of Dairy Science*, *97*(6), pp.3606-3614. https://doi.org/10.3168/jds.2013-7655

Scherpenzeel, C., den Uijl, I., van Schaik, G., Riekerink, R., Hogeveen, H. and Lam, T., 2016. Effect of different scenarios for selective dry-cow therapy on udder health, antimicrobial usage, and economics. *Journal of Dairy Science*, 99(5), pp.3753-3764. https://doi.org/10.3168/jds.2015-9963

Scherpenzeel, C., Hogeveen, H., Maas, L. and Lam, T., 2018. Economic optimization of selective dry cow treatment. *Journal of Dairy Science*, 101(2), pp.1530-1539. https://doi.org/10.3168/jds.2017-13076

Scherpenzeel, C., Tijs, S., den Uijl, I., Santman-Berends, I., Velthuis, A. and Lam, T., 2016. Farmers' attitude toward the introduction of selective dry cow therapy. *Journal of Dairy Science*, 99(10), pp.8259-8266. https://doi.org/10.3168/jds.2016-11349

Van Boeckel, T.P., Brower, C., Gilbert, M., Grenfell, B.T., Levin, S.A., Robinson, T.P., Teillant, A. and Laxminarayan, R., 2015. Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, *112*(18), pp.5649-5654. https://doi.org/10.1073/pnas.1503141112

Winder, C., Sargeant, J., Kelton, D., Leblanc, S., Duffield, T., Glanville, J., Wood, H., Churchill, K., Dunn, J., Bergevin, M., Dawkins, K., Meadows, S. and O'Connor, A., 2019. Comparative efficacy of blanket versus selective dry-cow therapy: a systematic review and pairwise meta-analysis. *Animal Health Research Reviews*, 20(2), pp.217-228. https://doi.org/10.1017/S1466252319000306

Zecconi, A., Sesana, G., Vairani, D., Cipolla, M., Rizzi, N. and Zanini, L., 2018. Somatic cell count as a decision tool for selective dry cow therapy in Italy. *Italian Journal of Animal Science*, 18(1), pp.435-440. https://doi.org/10.1080/1828051X.2018.1532328

10. Acknowledgements

First and foremost, I would like extend my sincerest gratitude to my supervisor, professor Péter Kovács, for his guidance, advice and valuable knowledge throughout the course of this thesis.

I wish to pay special regards to Animal Health Ireland and "CellCheck" for allowing me to use their database to gather the information that formulated my thesis.

Many thanks to the farmers who took the time to speak to me and utilise their herds for the purpose of this thesis.

To Catherine McAloon and Frank O'Sullivan, whose helpful contributions and extensive knowledge on the topic did not go unnoticed.

To my family, without your undying patience and tolerance, I may have given up many times. For the unwavering support you gave during trying times, I thank you from the bottom of my heart.

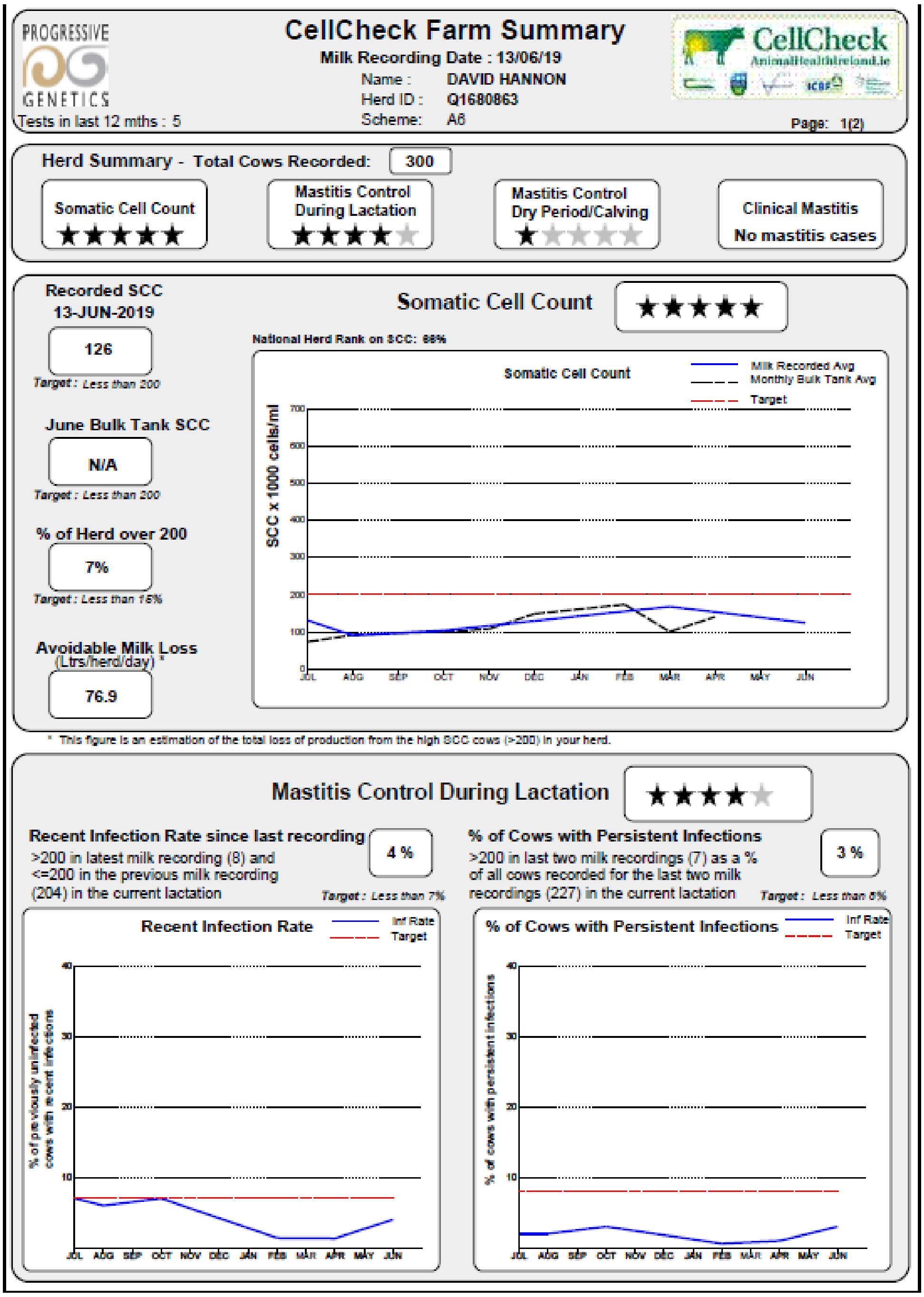
And finally, to my friends and fellow future Budapest graduates. We managed to get through, relatively, unscathed and it was for your constant encouragement that allowed this. I look forward to working with you our professional veterinary careers.

11. Appendices

Appendix 1:

<u>"CellCheck" reports</u>

The attached report is a sample of the reports used to gather all the information from each farm.



PROGRESSIVE GENETICS

CellCheck Farm Summary

Milk Recording Date : 13/06/19

Name : DAVID HANNON

Herd ID : Q1680863

Scheme: A6

Tests in last 12 mths : 5

CellCheck AnimalHealthIreland.ie

Page: 1(2)

Herd Summary - Total Cows Recorded: 300

Somatic Cell Count ★★★★★

Mastitis Control During Lactation ★★★★

Mastitis Control Dry Period/Calving ★

Clinical Mastitis No mastitis cases

Recorded SCC 13-JUN-2019: 126

Target : Less than 200

June Bulk Tank SCC: N/A

Target : Less than 200

% of Herd over 200: 7%

Target : Less than 15%

Avoidable Milk Loss (Ltrs/herd/day) *: 76.9

Somatic Cell Count ★★★★★

National Herd Rank on SCC: 66%

* This figure is an estimation of the total loss of production from the high SCC cows (>200) in your herd.

Mastitis Control During Lactation ★★★★

Recent Infection Rate since last recording: 4 %

>200 in latest milk recording (8) and <=200 in the previous milk recording (204) in the current lactation

Target : Less than 7%

% of Cows with Persistent Infections: 3 %

>200 in last two milk recordings (7) as a % of all cows recorded for the last two milk recordings (227) in the current lactation

Target : Less than 5%

CellCheck Farm Summary

PROGRESSIVE GENETICS

Tests in last 12 mths : 5

Milk Recording Date : 13/06/19

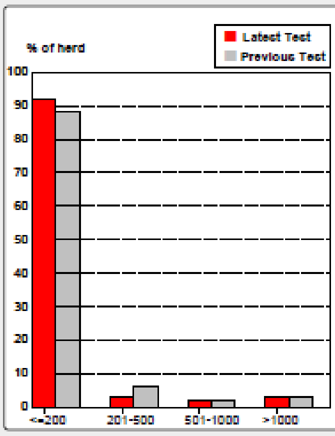
Name : DAVID HANNON

Herd ID : Q1680863

Scheme: A6

Page: 2(2)

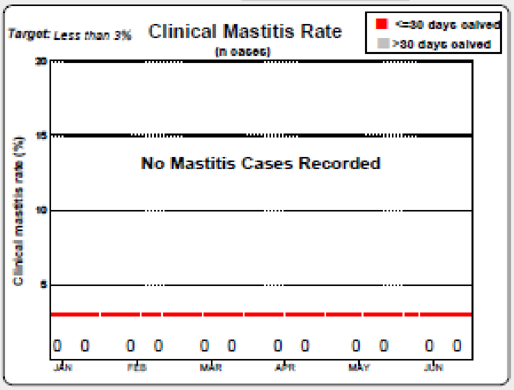
Herd SCC Distribution



Target: 85% of herd less than 200

Clinical mastitis

No mastitis cases



Note: Record treatments in the Record Events section of the ICBF web site www.icbf.com

Mastitis Control: Dry Period/Calving

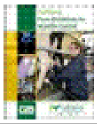
★☆☆☆☆

Note: Cows with first recording >60 days after calving are not included.

	First Test since calving	All calvings in current lactation
New infection rate over the dry period		
Cows No. of cows calved that had a SCC <=200 in recording prior to calving (10) and >200 in the current recording (0).	0% *Target: Less than 10%*	8% 13/17 *Target: Less than 10%*
Heifers No. of heifers that had a SCC >200 in the current recording (1) as a percentage of all heifers calved (3).	33% *Target: Less than 15%*	12% 7/59 *Target: Less than 15%*
Cure rate over the dry period No. of cows calved that had a SCC >200 in recording prior to calving (1) and <=200 in current recording (0)	0% *Target: Greater than 85%*	62% 8/13 *Target: Greater than 85%*

For information on controlling somatic cell counts and clinical mastitis, check the Cell Check Farm Guidelines for Mastitis Control.

	Farm Guideline No
Somatic Cell Counts	11-12
Mastitis Control: During Lactation	5-15 & Management Note M
Treatments During Lactation	10 & Management Notes B & G
Mastitis Control: Calving/Dry Period	1-4 & 16-20



Farm Guidelines book is available from your Co-op and local Veterinary Practitioners.

For further advice on controlling somatic cell counts and mastitis, contact your local CellCheck advisor.
Further information on the CellCheck Programme is available on www.cellcheck.ie

Appendix 2

Copyright declaration

HuVetA

ELECTRONIC LICENSE AGREEMENT AND COPYRIGHT DECLARATION*

Name:...Clíodhna O'Sullivan...

Contact information (e-mail):...Cliodhna.sullivan@gmail.com...

Title of document (to be uploaded):...The use of selective antibiotic dry cow therapy in Ireland, its role in reducing antimicrobial usage and its effect on animal health, milk quality and its economic effects.

Publication data of document:...2020...

Number of files submitted:...1...

By accepting the present agreement the author or copyright owner grants non-exclusive license to HuVetA over the above mentioned document (including its abstract) to be converted to copy protected PDF format without changing its content, in order to archive, reproduce, and make accessible under the conditions specified below.

The author agrees that HuVetA may store more than one copy (accessible only to HuVetA administrators) of the licensed document exclusively for purposes of secure storage and backup, if necessary.

You state that the submission is your original work, and that you have the right to grant the rights contained in this license. You also state that your submission does not, to the best of your knowledge, infringe upon anyone's copyright. If the document has parts which you are not the copyright owner of, you have to indicate that you have obtained unrestricted permission from the copyright owner to grant the rights required by this Agreement, and that any such third-party owned material is clearly identified and acknowledged within the text of the licensed document.

The copyright owner defines the scope of access to the document stored in HuVetA as follows (**mark the appropriate box with an X**):

- [X] I grant unlimited online access,
- [ ] I grant access only through the intranet (IP range) of the University of Veterinary Medicine,
- [ ] I grant access only on one dedicated computer at the Ferenc Hutÿra Library,
- [ ] I grant unlimited online access only to the bibliographic data and abstract of the document.

Please, define the **in-house accessibility of the document** by marking the below box with an **X**:

[X] I grant in-house access (namely, reading the hard copy version of the document) at the Library.

If the preparation of the document to be uploaded was supported or sponsored by a firm or an organization, you also declare that you are entitled to sign the present Agreement concerning the document.

The operators of HuVetA do not assume any legal liability or responsibility towards the author/copyright holder/organizations in case somebody uses the material legally uploaded to HuVetA in a way that is unlawful.

Date: Budapest, ..18...day ....11.....month...2020...year

Clodagh O'Sullivan

Author/copyright owner
signature

***HuVetA Magyar Állatorvos-tudományi Archívum – Hungarian Veterinary Archive** is an online veterinary repository operated by the Ferenc Hutÿra Library, Archives and Museum. It is an electronic knowledge base which aims to collect, organize, store documents regarding Hungarian veterinary science and history, and make them searchable and accessible in line with current legal requirements and regulations.*

HuVetA relies on the latest technology in order to provide easy searchability (by search engines, as well) and access to the full text document, whenever possible.
Based on the above, HuVetA aims to:

- *increase awareness of Hungarian veterinary science not only in Hungary, but also internationally;*
- *increase citation numbers of publications authored by Hungarian veterinarians, thus improve the impact factor of Hungarian veterinary journals;*
- *present the knowledge base of the University of Veterinary Medicine Budapest and its partners in a focussed way in order to improve the prestige of the Hungarian veterinary profession, and the competitiveness of the organizations in question;*
- *facilitate professional relations and collaboration;*
- *support open access.*

Appendix 3

<u>Supervisor counter-signature form</u>

Appendix 4. Supervisor counter-signature form

I hereby confirm that I am familiar with the content of the thesis entitled
The use of selective antibiotic dry cow therapy in Ireland, its role in reducing antimicrobial usage and its effect of animal health, milk quality and its economic effect
written by Cliodhna O'Sullivan (student name)

which I deem suitable for submission and defence.

Date: Budapest, 13 day 11 month 2020 year

Dr. Kovács Péter

Supervisor name and signature

Department of Animal Hygiene
Herd Health and Mobile Clinic

Department