Selective Dry Cow Therapy: the effect of different selection criteria on costs, antibiotic use and mastitis infections at Dutch dairy farms

Minor thesis Business Economics

Student:	Luuk Maas
Registration number:	900812537040
Course Code:	BEC-80424
Supervisor(s):	Henk Hogeveen (Business Economics Group, Wageningen University)
	Christian Scherpenzeel (Gezondheidsdienst voor Dieren)
	Theo Lam (Gezondheidsdienst voor Dieren)
Period:	02/09/2013- 06/01/2014

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Abstract

Treatment and control of mastitis is of major importance for the dairy sector. Mastitis leads to high costs because of the major production losses and treatment costs. In addition, mastitis impairs milk quality and cows suffering from mastitis leads to poor animal welfare. Because of the pleasure of the dairy farmer to work with healthy animals, mastitis is also undesirable.

Since 2014, it is no longer allowed in the Netherlands to use dry cow antibiotics in primiparous cows with a SCC < 150,000 cells/mL and multiparous cows with a SCC < 50,000 cells/mL on their last milk recording before drying off, which may not be older than 6 weeks.

Therefore the aim of this study was to investigate the effect of selective dry cow therapy on the costs and mastitis cases. This was done in two parts, a simulation and an optimization phase. For the optimization phase a linear programming model was built.

This study showed that there is a difference between heifers and cows in terms of mastitis dynamics and dry cow therapy. Each animal, heifer or cow, has its own optimal selection criterium, based on the SCC at drying off when antibiotics are restricted.

The use of antibiotics at drying off reduces the risk of development of (sub)clinical mastitis. But not all the animals on a dairy farm need antibiotics at drying off to prevent them from an intramammary infection during the dry period.
When the management around DCT is optimal, between 30 and 35% of the antibiotics used at drying off do not have a reducing effect on the amount of mastitis cases and therefore increase the economic costs of DCT unnecessarily. But because of the low costs of antibiotics and the high costs of mastitis the use of antibiotics is applied very frequently in practice to reduce the risk of mastitis and the associated high economic costs.

On a low BTSCC farm, more animals with lower economics costs are present, as compared to a Dutch average farm and a high BTSCC farm. Therefore low BTSCC farms have in general the lowest economic costs for mastitis management.
Due to a higher number of animals with a low SCC, the economic risk for SDCT is lower and easier to control on a low BTSCC farm.

Based on lowest economic costs of mastitis the use of teat sealants will cause a change on the selected animals for SDCT from no antibiotics used in heifers with a SCC<150.000 cells/mL to no antibiotics used in heifers with a SCC<150.000 cells/mL and cows with a SCC<50.000 cells/mL.

2. Introduction

Treatment and control of mastitis is of major importance for the dairy sector. Mastitis leads to high costs because of the major production losses and treatment costs (Hogeveen et al., 2011). In addition, mastitis impairs milk quality (Barbano et al., 2006) and cows suffering from mastitis leads to poor animal welfare (Kemp et al., 2008). Because of the pleasure of the dairy farmer to work with healthy animals, mastitis is also undesirable.

Since the 1970s there is the 5 Points Mastitis Control Plan to control mastitis (Neave et al., 1969). One of the points recommended is the use of blanket dry cow therapy (BDCT) to control the risk of new intramammary infections (**IMI**) during the dry period (Dodd et al., 1969).

There are two main reasons to use antimicrobial dry cow therapy (**DCT**) for heifers and dairy cows. The first reason is more preventive by protecting healthy quarters against IMI caused by pathogens. The other reason is to eliminate IMI present in infected udders (Eberhart, 1986, Bradley and Green, 2001). Several studies have shown that the use of antibiotics at drying off reduced the number of clinical mastitis cases in the dry period and early lactation, as compared to untreated cows (Schukken et al., 1993, Bradley and Green, 2000). Bradley and Green (2000) showed that from the environmental clinical mastitis cases that occurred in the first 100 days in milk (**DIM**) about 50% was already infected in the dry period. Therefore DCT is of great importance.

The dry period is the best period to use antibiotics, because of the long duration of treatment, which makes a therapy more effective (St.Rose et al., 2003), and the fact that cows are not lactating, therefore no production losses occur due to withdrawal periods.

Over the years, udder health improved, due to the implementation of this 5 Points Mastitis Control Plan, besides more research regarding mastitis management and the knowledge transfer towards dairy farmers (Lam et al., 2013).

(Schukken et al., 2003) stated 3 major issues according to mastitis prevention; 1. The limit to the SCC in milk for human consumption 2. Animal welfare issues, like clinical mastitis, may be a severe and painful disease that causes stress to the animal 3. Human health regarding milk consumption. This includes antibiotic residues in milk, which can cause antibiotic resistance. Approximately 80% of antibiotic residues in milk can be traced back to mastitis treatments, either during lactation or during the dry period (Ruegg and Tabone, 2000).
In the period 2005-2010 about 90% of all the dairy cows are treated with antibiotics during the dry period in the Netherlands (Lam et al., 2013). Even more (99%) of the lactating dairy cows in the UK receive dry cow antibiotic therapy at drying off (Berry and Hillerton, 2002c).

About 60% of the antibiotics used on dairy farms is applied in the udder, from which 2/3 is used for DCT (Hage and Van Deur) (as cited in (Den Uijl et al., 2012). Restrictive and prudent use of antibiotics in the dairy industry can be achieved by using alternatives for blanket DCT which uses standard antibiotics for every single quarter in every cow at drying off.

Because of the increasing antibiotic bacterial resistance and the economic incentives, selective dry cow therapy (**SDCT**) was introduced in the Netherlands, where only cows with an intramammary infection are selected to receive antibiotics at drying off. Not all quarters are infected with mastitis pathogens and therefore preventive antibiotic use is abandoned and only infected quarters will be treated in the dry period. In this way the total amount of antibiotics used at drying off can be reduced. SDCT is based on cow characteristics, such as Somatic Cell Count (**SCC**) (on the last milk recording) before drying off and or clinical mastitis history (Halasa et al., 2010b). A meta-analysis done by (Halasa et al., 2009c, Halasa et al., 2009d) showed that SDCT is higher protective against new IMI when compared to no DCT. It was also shown that blanket DCT gives more protection against new IMI as compared to SDCT.

In 2008 different animal sectors in the Netherlands, including the dairy sector, signed the "Convenant antibioticaresistentie dierhouderij", which stands for more prudent use of veterinary antibiotics in the Netherlands. The goal of the convenant was to promote restrictive and prudent use of antibiotics and thereby positive increase of the public opinion (Den Uijl et al., 2012). Therefore the Stuurgroep ABRES-Rund focused on reducing preventive antibiotic use at drying off in animals with a low SCC in a large field trial in the Netherlands, performed by GD Animal Health, Deventer. (Den Uijl et al., 2012).

In response to the conclusions of this field trial, a new guideline for veterinarians was adopted by the government in the Netherlands, which says that it is no longer allowed to use antibiotics at drying off in primiparous cows with a SCC < 150,000 cells/mL and multiparous cows with a SCC < 50,000 cells/mL on their last milk recording before drying off, which may not be older than 6 weeks. (diergeneeskunde, 2013)

Due to this selection criteria, the amount of antibiotics used at drying off will be reduced. The number of clinical mastitis cases will increase slightly due to the antibiotic reduction (Den Uijl et al., 2012). To minimize this negative effect and to control mastitis, optimization of the udder health management on cow and farm-level is crucial. Attention should be paid to a clean environment, like the concrete floor and cubicles. A low quantity of *S. aureus* in bulk milk and a low milk-yield at drying off. Proper adjustment of the milking machine and animals free of infections and stress. (Den Uijl et al., 2012).

Costs associated with mastitis and mastitis control around the dry period are highest for no DCT and lowest for SDCT with BDCT in between, although differences between treatment strategies are small. Blanket DCT has the lowest variation in costs, followed by SDCT and no DCT. Therefore, the most optimal treatment strategy depends on the risk attitude of the farmer and strict selection criteria for animals that will or will not be treated. (Huijps and Hogeveen, 2007)

In the study done by (Huijps and Hogeveen, 2007) it was assumed that it was possible to select the right animals for non-antibiotic treatment. However it was stated that in practice it is still unknown which animals should be selected for the SDCT. In addition the variation in costs are high for SDCT, which makes SDCT still not economically beneficial. Also few research is done at antibiotic restrictions and its economic effect.

Therefore the aim of this study is to investigate the effect of SDCT on the costs and mastitis cases. Additionally the animal selection for SDCT will be investigated to see if there are differences between animals to optimize selection criteria for animals for SDCT on different types of farms.
In this context the effect of SDCT in different scenarios with different selection criteria for animals to receive SDCT are investigated. The specific objectives were to develop a model that could examine changes in (sub-)clinical mastitis rate; to examine changes in costs; and to create a mathematical tool to facilitate the joint optimization of reduction in (sub-)clinical mastitis cases with optimal antibiotic reduction and reduced costs.

This study will give a first summary about the effect of SDCT at different antibiotic restrictions. The results and conclusions can be used by dairy farmers to help them to select the right animals for SDCT to reduce the economic costs and to minimize the risk of variation in the costs.

3. Material and methods

3.1 Model overview

The study consist of two modelling parts. In the first, simulation of different scenarios took place and in the second part optimization took place to see the effect with a constraint on the antibiotics used. A statistic deterministic linear programming model was used for the second part.

Linear programming has proven to be one of the most powerful tools for analysis of resource allocation choices at the firm and sector level. In its simplest form, linear programming is a method which is used to optimize profit by finding the optimal combination of different parameters/input with respect to a set of fixed constraints (Norton, 1986).

An important point to answer the main question is to determine whether antibiotics should be used at drying off. The animals on the farm were categorized in several groups based on their SCC on the last milk recording before drying off and for each group a decision can be made on the use of antibiotics at drying off. Linear programming was used in this situation to distribute the antibiotics at drying off over the groups, with the goal to minimize costs.

In this study only animals with a low SCC were included, because a high SCC is highly associated with an IMI (Schukken et al., 2003) and should therefore be treated during the dry period.

Based on the SCC results of the last milk recording before drying off, the low SCC dairy cows are divided into seven groups. Each group consists of two activities, either dried off with antibiotics or not. Therefore there are 14 activity levels in the model (table 3.1). Heifers are animals at the end of their first lactation. The cows are at the end of their second or further lactation.

Table 3.1 Distribution of the animals to the model based on the SCC results on the last MPR before drying off.

Group no.	Activity number (Xi)		Animal	Somatic Cell Count (cells/mL)
	Dried off with antibiotics	Not dried off with antibiotics		
1	1	2	Heifer	0-50,000
2	3	4	Cow	0-50,000
3	5	6	Heifer	50,000-100,000
4	7	8	Cow	50,000-100,000
5	9	10	Heifer	100,000-150,000
6	11	12	Cow	100,000-150,000
7	13	14	Cow	150,000-250,000

From the environmental clinical mastitis cases that occurred in the first 100 DIM about 50% was already infected during the dry period (Bradley and Green, 2000). Therefore the animals during the dry period and first 100 DIM were followed.

Simulation phase

The following mathematical formulation refers to the model used in the simulation phase:

$$Z = \sum Ci * Xi$$

$$Z = Total\ economic\ costs$$
$$Ci = Economic\ costs\ \ per\ unit\ of\ activity$$
$$Xi = Activities$$

For the simulation phase the objective function is the sum of the Total Costs Mastitis (**TCM**) of each activity multiplied by the number of animals per activity. The TCM consists of the Total Costs Clinical Mastitis **(TCCM)**, Total Costs Subclinical Mastitis **(TCSM)** and the Total Costs of Antibiotics **(TCAB)**. Both, TCSM and TCCM, consist of the Probability for Subclinical Mastitis & Probability for Clinical Mastitis **(PSCM** & **PCM)** multiplied by the Costs for Subclinical mastitis and Costs Clinical Mastitis **(CSM** & **CCM).** The Total Costs of Antibiotics **(TCAB)** consist of the labor costs and the costs of the antibiotic product.
The number of activities in the model is fourteen because of the seven groups and the possibility for the use of antibiotics or not at drying off. Every time the economic costs per unit of activity is multiplied by the activity, which is the number of animals in each activity and all these calculations are summed up.

$$Z = \sum_{i=1}^{14} Total\ Costs\ Mastitis\ (TCM)\ i * Xi$$

$$Z = total\ economic\ costs\ related\ to\ mastitis$$

$$in\ the\ dry\ period\ and\ first\ 100\ days\ in\ lactation$$

$$TCM\ i = Total\ Costs\ Clinical\ Mastitis\ (TCCM)i + Total\ Costs\ Subclinical\ Mastitis\ (TCSM)i + Total\ Costs\ Antibiotics\ (TCAB)$$

$$TCCM\ i = Probability\ \ Clinical\ Mastitis\ (PCM)i * Costs\ Clinical\ Mastitis\ (CCM)$$

$$TCSM\ i = Probability\ Subclinical\ Mastitis\ (PSCM)i * costs\ subclinical\ mastitis\ (CSM)$$

$$CSM = Milkproduction\ losses\ due\ to\ subclinical\ mastitis\ (ML) * duration\ milkproduction\ lossses\ (DML) * loss\ costs\ (LS)$$

$$LS = Milkprice\ (MP) -\ \ Concentrate\ feed\ costs\ (CFC)$$

$$TCAB = \left(\frac{hourly\ wage\ (HW)}{60}\right) * \ required\ time\ for\ drying\ off\ (RTD) \\ + costs\ per\ 4\ antibiotic\ injectors\ (CABI)$$

Optimization phase

For the simulation phase of the study a linear programming model was used. The linear programming model will, per group, divide the animals between the use of antibiotics at drying off or no use of antibiotics at drying off. When the costs related to mastitis and drying off are higher for the option were no antibiotics are used at drying off when compared to the use of antibiotics at drying off, the cheapest option is optimal. When the use of antibiotics is restricted, the decision will also be based on the amount of antibiotics needed per option. In general the model tries to find the optimum distribution of the animals over the activity levels.

As output, the linear programming model will give the number of animals suffering a (sub)clinical mastitis, amounts of antibiotics used, the total economic costs related to mastitis in the dry period and first 100 DIM and the number of animals per group which either receive antibiotics or not at drying off.

The mathematical formulation for the linear programming model is almost equal to the formulation used in the simulation phases. Only an objective function is set and restrictions are added. The solving method used in the linear programming model was LP Simplex engine which is used for linear solver problems.

The following mathematical formulation is standard for a linear programming model:

$$MIN\ Z = \sum Ci * Xi \qquad (objective\ function)$$
$$\sum Aij * Xi \ \leq Bj \qquad (restrictions)$$
$$Xi \ \geq 0$$

$Z = Total\ economic\ costs$
$Ci = Economic\ costs\ \ per\ unit\ of\ activity$
$Xi = Activities$
$Aij = Technical\ coefficients\ per\ unit\ of\ activity$
$Bj = Resources$

The MIN in the formula indicates the objective function to minimize the economic costs related to prevention and cure of mastitis in the dry period and first 100 DIM. The second line indicates the restrictions, which are used and the last line in the formula makes sure that no negative numbers of animals are used.

For the linear programming model in the objective function the MIN was added.

$$MIN\ Z = \sum_{i=1}^{14} Total\ Costs\ Mastitis\ (TCM)\ i * Xi$$

There are restrictions on the animal groups and the antibiotic use in the model. The number of animals dried off with or without antibiotics together should be equal to the number of animals per group. This is to make sure that all animals are included in the model. Otherwise the model should chose no animals because than the economic costs are lowest. Therefore the uneven X indicates the use of antibiotics at drying off and the even X indicates drying off without antibiotics in the following formulas.

$$1 * X1 + 1 * X2 = number\ of\ animals\ in\ group\ 1$$

$$1 * X3 + 1 * X4 = number\ of\ animals\ in\ group\ 2$$

$$1 * X5 + 1 * X6 = number\ of\ animals\ in\ group\ 3$$

$$1 * X7 + 1 * X8 = number\ of\ animals\ in\ group\ 4$$

$$1 * X9 + 1 * X10 = number\ of\ animals\ in\ group\ 5$$

$$1 * X11 + 1 * X12 = number\ of\ animals\ in\ group\ 6$$

$$1 * X13 + 1 * X14 = number\ of\ animals\ in\ group\ 7$$

There are restrictions as well on the antibiotic use. The restriction (B) was set on different levels during the study. The antibiotic use **(AB use)** was calculated by the use of antibiotics at drying off **(ABD)** plus the use of antibiotics for treatment of an IMI **(ABT)**.

$$\sum_{i=1}^{14} AB\ usei * Xi \ \leq B$$

$$AB\ use\ for\ (i\ is\ uneven) = Antibiotic\ use\ for\ drying\ off (ABD) + PCMi * Antibiotic\ use\ for\ treatment (ABT)$$

$$AB\ use\ for\ (i\ is\ even) = PCMi * Antibiotic\ use\ for\ treatment (ABT)$$

3.2 Model parameterization

Classification of the animals

The model was based on a fictive dairy farm with 100 dairy cows. The farm herd distribution is as follows: 33.2% heifers, 24% second lactation cows and 42,8% multiparous cows. Because main interest of the study is about antibiotics used at drying off the model does not take the heifers into account, because they are not dried off before their first lactation.
In a year 33,2% of the animals are replaced. Most of the time, the farmer decides whether or not to replace an animal in the upcoming year. For example because of a low production or all kind of diseases. Due to different reasons there are also animals which are dried off, but also will be replaced in one year. As an assumption 85% of the replaced animals are not dried off. It is assumed that the chance to be replaced is equal for a heifer, second lactation or a multiparous cow.
Due to a prolonged calving interval not all the animals are dried off in one year. Due to these different reasons only a small amount of the animals are available for dry cow treatment in a year(Den Uijl et al., 2012).

In the simulation phase of the study, the animal distribution over the seven groups was based on a Dutch average farm and two more farm types were added, a high Bulk tank somatic cell count (BTSCC) farm (>=250,000<400,000 cells/mL) (Den Uijl et al., 2012) and a low Bulk Tank Somatic Cell Count (BTSCC) farm (<100,000 cells/mL). The animal distribution of both high and low BTSCC farms are based on the study of (Huijps et al., 2008).

Less animals were included in the model (21 animals) for the high BTSCC farm because less animals have a low SCC in this farm type. Due to the low SCC on the low BTSCC farm more animals were included (42 animals) for this farm type (table 3.2).

Table 3.2 Rounded distribution of the animals of the three different farm types over the seven groups.

Group no.	Animal	Somatic Cell Count *1000 (cells/mL)	Number of animals included in the model.		
			Dutch average farm	High BTSCC farm	Low BTSCC farm
1	Heifer	0-50	6	2	12
2	Cow	0-50	4	4	22
3	Heifer	50-100	4	3	2
4	Cow	50-100	5	5	4
5	Heifer	100-150	2	2	0
6	Cow	100-150	5	3	1
7	Cow	150-250	5	3	1
		total	32	21	42

Risk of mastitis

The obtained data of the mastitis chance from the GD Animal Health are listed in table 3.3. In the study done by the GD Animal Health a split-udder design was used. The available data were not directly applicable in our model.

The column quarters with clinical mastitis/ quarters at risk in table 3.3 indicates the chance for a clinical mastitis per quarter. The column animals with clinical mastitis/ animals at risk indicates the number of animals which are infected. Due to the split-udder design each cow undergoes two different treatment-regimens.

When there are four quarters with the same treatment, each quarter can infect three others. But in the used split-udder design, there are only 2 quarters with the same treatment per cow. Therefore it is not possible to just multiply the chance per quarter by four.
The most suitable way to come from a risk at quarter level to a risk at cow level is to first translate the risk per quarter to the risk per udderhalf. And thereafter translate the risk per udderhalf to the risk per cow. See the following formula.

$$PCMi = \left(\frac{animal\ risk\ for\ clinical\ mastitis}{quarter\ risk\ for\ clinical\ mastitis}\right) * animal\ risk\ for\ clinical\ mastitis * 100\%$$

An example of the calculation is done for the SCC group 0-50,000 cells/mL:
(3.1%) / (5.56%)* (5.56%)*100%= 9.94%

It is shown that heifers have a lower chance on a clinical mastitis as compared to cows. Keep in mind that the term heifers means the chance for an IMI in their second lactation. In general, the risk increases with higher SCC on the last milk recording before drying off for both heifers and older cows (table 3.4). The use of antibiotics has a positive effect on the reduction of IMI. The PCMi is lower when using antibiotics at drying off when compared to using no antibiotics at drying off in general (table 3.4).

Table 3.3 Risk of getting an IMI during the dry period and the first 100 days in lactation for heifers and cows in their subsequent dry period and lactation, based on the SCC at the last MPR before drying off.

Group no.	Animal	Somatic Cell Count *1000 (cells/mL)	Treated with antibiotics at drying off		Not treated with antibiotics at drying off	
			Quarters with clinical mastitis/ quarters at risk	Animals with clinical mastitis/ animals at risk	Quarters with clinical mastitis/ quarters at risk	Animals with clinical mastitis/ animals at risk
1	Heifer	0-50	19/612=3.10%	17/306=5.56%	18/612=2.94%	18/306=5.88%
2	Cow	0-50	16/382=4.19%	14/191=7.33%	23/382=6.02%	21/191=10.99%
3	Heifer	50-100	14/452=3.09%	12/226=5.31%	16/452=3.54%	14/226=6.19%
4	Cow	50-100	25/606=4.13%	24/303=7.92%	64/606=10.56%	51/303=16.83%
5	Heifer	100-150	6/178=3.37%	6/89=6.74%	10/178=5.62%	9/89=10.11%
6	Cow	100-150	16/546=2.93%	14/273=5.13%	28/546=5.13%	27/273=9.89%
7	Cow	150-250	23/464=4.96%	21/232=9.05%	39/464=8.41%	33/232=14.22%

Table 3.4 Risk for a clinical mastitis at animal level per group (PCMi).

Group no.	Animal	Somatic Cell Count *1000 (cells/mL)	Activity number (Xi)	Treated with antibiotics at drying off.	Activity number (Xi)	Untreated with antibiotics at drying off.
1	Heifer	0-50	1	9.94%	2	11.76%
2	Cow	0-50	3	12.83%	4	20.08%
3	Heifer	50-100	5	9.10%	6	10.84%
4	Cow	50-100	7	15.21%	8	26.83%
5	Heifer	100-150	9	13.48%	10	18.20%
6	Cow	100-150	11	8.97%	12	19.07%
7	Cow	150-250	13	16.53%	14	24.07%

The risk of getting a subclinical mastitis during the dry period and the first 100 DIM was investigated in an earlier study, done by GD Animal Health. Because of the split-udder design the results were based on the half of an udder. To come from a risk at a half udder to a risk at cow level the quarter with the highest SCC was multiplied by 1.3 and the quarter with the lowest SCC by 2.7 the total SCC was divided by 4 to come to a SCC at animal level. The positive effect of antibiotics is also visible for subclinical mastitis according to the PSCMi (table 3.5).

Table 3.5 Risk for a subclinical mastitis at animal level per group (PSCMi).

Group no.	Animal	Somatic Cell Count *1000 (cells/mL)	Activity number (Xi)	Treated with antibiotics at drying off.	Activity number (Xi)	Untreated with antibiotics at drying off.
1	Heifer	0-50	1	4.78%	2	7.17%
2	Cow	0-50	3	7.26%	4	17.32%
3	Heifer	50-100	5	10.60%	6	18.98%
4	Cow	50-100	7	13.59%	8	18.82%
5	Heifer	100-150	9	8.24%	10	17.65%
6	Cow	100-150	11	15.65%	12	24.81%
7	Cow	150-250	13	18.35%	14	31.65%

In the simulation phase the use of a teat sealant at drying off was included as well. When antibiotics and teat sealants were both added at drying off, no extra effect of the teat sealant was found in low SCC animals (Bradley et al., 2010). When only a teat sealant was used at drying off the preventive effect of the teat sealant is around 28% (Berry and Hillerton, 2002a); (Rabiee and Lean, 2013). Therefore the chance for a clinical mastitis for the even activity numbers was multiplied by 0.72 in this study. The chance for a subclinical mastitis was not changed because more research was needed to find the protectice effect of teat sealants for a subclinical mastitis (Rabiee and Lean, 2013).

Antibiotic use

At drying off four injectors of antibiotics are used, one per quarter, which makes it 4 daily dosages for the dry period up to 100 DIM and treatment of an IMI (ABD). All the animals which are treated with antibiotics at drying off have at least 4 daily dosages/100 days **(DD/100 days)**. Besides the preventive use of antibiotics, antibiotics are used to cure an existing IMI. It is assumed that on average a clinical mastitis infection is cured by three tubes (one tube every 12 hours), which makes it 1.5 daily dosages/100 days (ABT). As an example, an animal which is dried off with antibiotics and also cured from a clinical mastitis will have 4 (ABD)+1.5 (ABT)= 5.5 daily dosages/100 days (AB use).
For example an animal from group 1 X 1, treated with antibiotics at drying off will have 4 + (9.94%*1.5)= 4.15 daily dosages/100 days.

Economic costs

The economic input data (table 3.6) can be filled in the calculations to calculate the total costs of mastitis. It is assumed that the costs for teat sealants are the same as the Total Costs Antibiotics (TCAB) and are added to the total costs in the simulation phase.

Table 3.6 Input values for economic parameters for calculating the total costs mastitis with their abbreviations and source.

Parameter	Abbreviation	Value	Source
Costs clinical mastitis	CCM	€221	Based on (Huijps et al., 2008)
Milk production losses due to subclinical mastitis	ML	0.87 kg/day	Based on (Halasa et al., 2009a)
Duration milk production losses	DML	219 days	McInerney et al., 1992 as cited in (Halasa et al., 2009a)
Milk price	MP	€0,32/kg	(AMRO, 2011)
Concentrate feed costs	CFC	€0,05/kg	(Huijps et al., 2008)
Hourly wage	HW	€18/hour	(Huijps et al., 2008)
Required time for drying off	RTD	3 minutes	Own experience
Costs per 4 antibiotic injectors	CABI	€10	(Den Uijl et al., 2012)

3.3 Scenarios

Simulation phase

For the simulation, 36 scenarios were developed to see the effects of different DCT strategies. All 36 scenarios were based on six different scenarios (table 3.7). In the first scenario the most preventive way of antibiotic use at drying off is investigated, where all animals are dried off with antibiotics. In the following scenarios less animals are dried off with dry cow antibiotics and in the last scenario no dry cow antibiotics are used in any of the animals (table 3.7). Keep in mind that the study will only focus on low SCC animal. The high SCC animals will always dried of with antibiotics but are not investigated during this study.

To extend the scenarios, the six scenarios were repeated but this time the use of teat sealant at drying off was included, which makes it twelve different scenarios. These twelve scenarios were applied on three different types of farms based on BTSCC; Dutch average, high BTSCC and low BTSCC farms (table 3.8).

Table 3.7 The six main scenarios used with a decreasing antibiotic use.

Scenario no.	Details
1	Dry cow antibiotics are used in all low SCC animals
2	No dry cow antibiotics are used in animals with a SCC <100,000
3	No dry cow antibiotics are used in animals with a SCC<50,000
4	No dry cow antibiotics are used in heifers with a SCC<150,000
5	No dry cow antibiotics are used in heifers with a SCC<150,000 and cows with a SCC<50,000
6	No dry cow antibiotics are used in any of the animals

Table 3.8 List of all scenarios differentiated over three different farm types.

Scenario no.	Details
Average Dutch farm	
1	Antibiotics are used on all low SCC animals at drying off.
2	No dry cow antibiotics are used at animals with a SCC <100,000
3	No dry cow antibiotics are used at animals with a SCC<50,000
4	No dry cow antibiotics are used at heifers with a SCC<150,000
5	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000
6	No dry cow antibiotics are used on any of the animals at drying off.
7	Dry cow antibiotics are used on all low SCC animals at drying off + teat sealant at all animals.
8	No dry cow antibiotics are used at animals with a SCC <100,000 + teat sealant at all animals.
9	No dry cow antibiotics are used at animals with a SCC<50,000 + teat sealant at all animals.
10	No dry cow antibiotics are used at heifers with a SCC<150,000 + teat sealant at all animals.
11	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000 + teat sealant at all animals applied.
12.	No dry cow antibiotics are used on any of the animals at drying off + teat sealant at all animals.
High BTSCC farm	
13	Dry cow Antibiotics are used on all low SCC animals at drying off.
14	No dry cow antibiotics are used at animals with a SCC <100,000
15	No dry cow antibiotics are used at animals with a SCC<50,000
16	No dry cow antibiotics are used at heifers with a SCC<150,000
17	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000
18	No dry cow antibiotics are used on any of the animals at drying off.
19	Dry cow antibiotics are used on all low SCC animals at drying off + teat sealant at all animals.
20	No dry cow antibiotics are used at animals with a SCC <100,000 + teat sealant at all animals.
21	No dry cow antibiotics are used at animals with a SCC<50,000 + teat sealant at all animals.
22	No dry cow antibiotics are used at heifers with a SCC<150,000 + teat sealant at all animals.
23	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000 + teat sealant at all animals applied.
24	No dry cow antibiotics are used on any of the animals at drying off + teat sealant at all animals.
Low BTSCC farm	
25	Dry cow antibiotics are used on all low SCC animals at drying off.
26	No dry cow antibiotics are used at animals with a SCC <100,000
27	No dry cow antibiotics are used at animals with a SCC<50,000
28	No dry cow antibiotics are used at heifers with a SCC<150,000
29	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000
30	No dry cow antibiotics are used on any of the animals at drying off.
31	Dry cow antibiotics are used on all low SCC animals at drying off + teat sealant at all animals.
32	No dry cow antibiotics are used at animals with a SCC <100,000 + teat sealant at all animals.
33	No dry cow antibiotics are used at animals with a SCC<50,000 + teat sealant at all animals.
34	No dry cow antibiotics are used at heifers with a SCC<150,000 + teat sealant at all animals.
35	No dry cow antibiotics are used at heifers with a SCC<150,000 and cows with a SCC<50,000 + teat sealant at all animals applied.
36	No dry cow antibiotics are used on any of the animals at drying off + teat sealant at all animals.

Optimization phase

Antibiotic restriction

This is the optimization part of the study. The linear programming model was used with a restriction on the antibiotics used. In this way the relationship between the antibiotics used, the number of clinical mastitis cases and the economic consequences were reflected.

The amount of antibiotics used in scenario 13, wherein most antibiotics are used, is 4.24 daily dosages per 100 days per animal on average. Therefore 4.24 was set on 100% antibiotics used. the antibiotic restriction will be reduced by steps of 5% and after every step the linear programming model was run. Due to this reduction in antibiotic use the linear programming model is forced to distribute the animals over the use of antibiotics at drying off or not to find the most optimal situation with the lowest economic costs related to mastitis in the dry period and first 100 days in lactation. After each step of the distribution per animal group was checked to see if there was a shift from antibiotic use at drying off towards no use of antibiotics (shift from an even activity X to an uneven X). Due to the linear programming model it is possible to see which group of animals is more sensitive and will shift.

Increasing and decreasing risk

In this part of the study the same method was used as described above in antibiotic restriction. This time the effect of an increasing or decreasing risk of intramammary infection was investigated which could be due to a more or less hygienic environment were the animals are exposed to.
It was assumed that when the animals are not treated with dry cow antibiotics the risk for an IMI will increase or decrease by 10%. Therefore the risks of a clinical mastitis (PCMi) by untreated animals (even activity numbers) stated in table 3.4 were multiplied by 0.9 and 1.1

4. Results

4.1 Simulation phase

All 36 scenarios are simulated to see the effect of antibiotic reduction on the costs per animal and the mastitis cases. In the first line of table 4.1 the results of the first scenario, where all animals were dried off with antibiotics on a Dutch average farm, are listed. The results are related to 32 animals from the 100 which are on the farm. The costs per animal are €44 and 12.19% of the 32 animals are suffering from a clinical mastitis and 11.44% of a subclinical mastitis. The total amount of antibiotics per animal used in this situation is 4.15 daily dosages/100 days.

In general, preventive use of dry cow antibiotics decreases the risk for an IMI and therefore the number of (sub)clinical mastitis cases. When the antibiotic use at drying off is decreased in the upcoming scenarios the number of (sub)clinical mastitis cases are increasing slightly. It is expected that the costs per animal will increase as well, but in some scenarios the costs per animal are lower when compared to the scenarios where all animals are dried off with the use of antibiotics. The costs per animal are lowest at the scenario were no antibiotics are used in heifers with a SCC <150,000 cells/mL for all three types of farms: €42.79 for the Dutch average farm, €44.10 for the high SCC farm and €39.69 for the low BTSCC farm (table 4.1).

Due to the use of teat sealants at drying off the number of clinical mastitis cases decreases, when compared to the scenarios were no teat sealants were used. In contrast, the costs per cows are higher due to the costs of the teat sealant. The costs per animal are minimal in the scenario where no antibiotics were used in heifers with a SCC <150,000 cells/mL and cows with a SCC <50,000 cells/mL for all three types of farms: €50.45 for the Dutch average farm, €52.09 for the high BTSCC farm and €46.91 for the low BTSCC farm. The use of teat sealants at drying off will therefore change the selection criteria for the animals which are used for SDCT which will reduce the use of antibiotics even more. For the Dutch average farm, high BTSCC farm and the low BTSCC farm the antibiotic reduction is respectively 2.63 VS 2.14; 3.00 VS 2.16; 2.78 VS 0.70

Table 4.1 gives an overview of the absolute differences between the numbers. In appendix 1 the differences between the numbers are given in percentages based on the scenario where all animals were dried off with antibiotics. This makes it more easy to compare the different scenarios and different components of the SDCT.

Table 4.1 Costs per animal (C/A), percentage of (sub)clinical cases (CMC & SMC) and antibiotic use per animal (AB use in daily dosages/100 days) for 12 different scenarios on a Dutch average-, low- and high BTSCC farm.

Sc no.	Details	C/A (€)	N	CMC (%)	SMC (%)	AB use (dd/100d)
Dutch average farm						
1	AB on all animals	44.00	32	12.19	11.44	4.15
2	No AB on SCC <100,000	46.75	32	15.59	15.09	1.75
3	No AB on SCC <50,000	44.13	32	13.41	13.09	2.92
4	No AB on heif SCC <150,000	42.79	32	13.03	13.56	2.63
5	No AB on heif SCC <150,000 cows SCC <50,000	44.03	32	13.91	14.75	2.17
6	No AB on all low SCC animals	51.62	32	18.66	19.28	0.28
7	AB on all animals + ts	54.90	32	12.19	11.44	4.15
8	No AB on SCC <100,000 + ts	51.01	32	12.63	15.09	1.70
9	No AB on SCC <50,000 + ts	52.11	32	12.09	13.09	2.90
10	No AB on heif SCC <150,000 + ts	50.71	32	11.72	13.56	2.61
11	No AB on heif SCC <150,000 cows SCC <50,000 + ts	50.45	32	11.91	14.75	2.14
12	No AB on all low SCC animals+ ts	50.86	32	13.44	19.28	0.20
High BTSCC farm						
13	AB on all animals	44.76	21	12.81	11.62	4.24
14	No AB on SCC <100,000	49.70	21	17.29	16.14	1.64
15	No AB on SCC <50,000	46.23	21	14.52	13.95	2.97
16	No AB on heif SCC <150,000	44.10	21	13.57	13.62	3.00
17	No AB on heif SCC <150,000 cows SCC <50,000	46.21	21	15.05	15.71	2.20
18	No AB on all low SCC animals	53.87	21	20.00	19.90	0.30
19	AB on all animals + ts	55.66	21	12.81	11.62	4.24
20	No AB on SCC <100,000 + ts	52.78	21	13.71	16.14	1.58
21	No AB on SCC <50,000 + ts	53.74	21	12.95	13.95	2.95
22	No AB on heif SCC <150,000 + ts	52.53	21	12.43	13.62	2.99
23	No AB on heif SCC <150,000 cows SCC <50,000 + ts	52.09	21	12.76	15.71	2.16
24	No AB on all low SCC animals+ ts	52.52	21	14.43	19.90	0.22
Low BTSCC farm						
25	AB on all animals	41.45	42	12.07	7.69	4.20
26	No AB on SCC <100,000	46.80	42	17.67	14.62	0.40
27	No AB on SCC <50,000	45.15	42	16.36	13.60	1.03
28	No AB on heif SCC <150,000	39.69	42	12.74	8.93	2.78
29	No AB on heif SCC <150,000 cows SCC <50,000	45.02	42	16.50	14.14	0.77
30	No AB on all low SCC animals	47.20	42	17.93	14.98	0.27
31	AB on all animals + ts	52.35	42	12.07	7.69	4.20
32	No AB on SCC <100,000 + ts	47.05	42	12.83	14.62	0.33
33	No AB on SCC <50,000 + ts	47.51	42	12.50	13.60	0.97
34	No AB on heif SCC <150,000 + ts	48.01	42	11.57	8.93	2.77
35	No AB on heif SCC <150,000 cows SCC <50,000 + ts	46.91	42	12.40	14.14	0.70
36	No AB on all low SCC animals+ ts	47.03	42	12.90	14.98	0.19

4.2 Optimization phase

Antibiotic restriction

In this part of the study, the effect of a restriction in antibiotic use is investigated. This is done by using the linear programming model. When the maximum antibiotic use is reduced in steps of 5%, the linear programming model optimized the situation by selecting the right criteria for animals for SDCT.

The maximum amount of antibiotics was reached in the high BTSCC farm in the scenario where all animals were dried off with antibiotics. The total amount of antibiotics used was 4.2414 dd/100 days per animal which makes 4.2414 * 21 = 89.07 dd/100 days. Therefore on the Dutch average farm the amount belonging to 100% is 4.2414 * 32 = 135.72 dd/100 days. For the low BTSCC farm the maximal amount of antibiotics used was 4.2414*42 animals = 178.14 dd/100 days.

After the first run of the model it was shown that not all of the 135.72 dd/100 days were used to find the optimum situation for the Dutch average farm. Only 91.49 dd/100 days are used. Even when a farmer is allowed to use dry cow antibiotics in all quarters of the animals on the farm, it is not beneficial to use them all. According to the high BTSCC farm 69.06 dd/100 days were used in the optimal situation. For the low BTSCC farm 118.09 dd/100 days were used.

The linear programming model gives several outputs after each run like the shadow prices. An interesting point is the shadow price of the antibiotics used. The shadow price indicates the price by which the objective will change when one extra unit of resource is used. After the first run without restrictions on antibiotics, the shadow price is €0,- for all three types of farms. This makes sense because in an optimal situation not all of the antibiotics are used like only 91.49 dd/100 days of the 135.72 dd/100 days were used. So when the maximum amount of 135.72 dd/100 days rises with one extra unit, the optimum situation will not be changed. The objective in this case are the total costs.

Later on when the allowable amount of antibiotics are decreased in steps of 5%, the antibiotics will be restrictive and the shadow price will change. When the maximum amount of antibiotics is reduced to 65% one extra dd/100 days of antibiotic could decrease the total costs by €2.65 at a low BTSCC farm. This shadow price stays the same at 70% antibiotic reduction. When only 10% of the total antibiotics are available the use of one extra antibiotic will decrease the costs by €4.58 When antibiotics are restricted a high BTSCC farm first see a negative effect on the total costs, followed by a Dutch average farm and a low BTSCC farm (table 4.2).

Table 4.2: change in shadow price at different amounts of allowable antibiotics per farm type.

Maximum amount of antibiotics used (%)	Maximum amount of antibiotics used per animal (dd/100 days)	Shadow price (€)		
		Low BTSCC farm	Dutch average farm	High BTSCC farm
100	4.24	0	0	0
65	2.76	-2.65	-1.11	-2.65
30	1.27	-2.65	-4.20	-4.20
10	0.42	-4.58	-4.58	-4.58

Due to the comparison of the antibiotics used per animal on daily dosages/100 days the three different farm types can be compared with each other. For each farm the antibiotic use is restricted by steps of 5% each time. The cost and cases of (sub)clinical mastitis stays at the same level till the moment where the ‘allowable’ amount of antibiotics are too low to fulfil the optimum situation.

From that moment the (sub)clinical mastitis cases are rising and therefore the economic costs too. The percentage allowed antibiotics decreases up to 10% because a lower antibiotic use is not possible otherwise IMI's can't be cured. (figure 1.)

Both the clinical mastitis chances and the economic costs are highest for the high BTSCC farm and lowest for the low BTSCC farm.
Due to the different distributions of the animals in the farms, the pattern of the costs differs. The high BTSCC farm reaches the maximum allowable amount of antibiotics somewhere around 70%. From upon that percentage less antibiotics are available as compared to the needs, as for the (sub)clinical mastitis cases and economic costs are rising. For the Dutch average and the low BTSCC farm this point appears on 60- 65% of the allowed antibiotics.
The differences between the Dutch average and the low BTSCC farm are greater at lower allowable amounts of antibiotics, because the line of the clinical mastitis chance is steeper from upon 30% of the allowed antibiotics (figure 1).
The underlying results of figure 1 can be found in appendix 2.

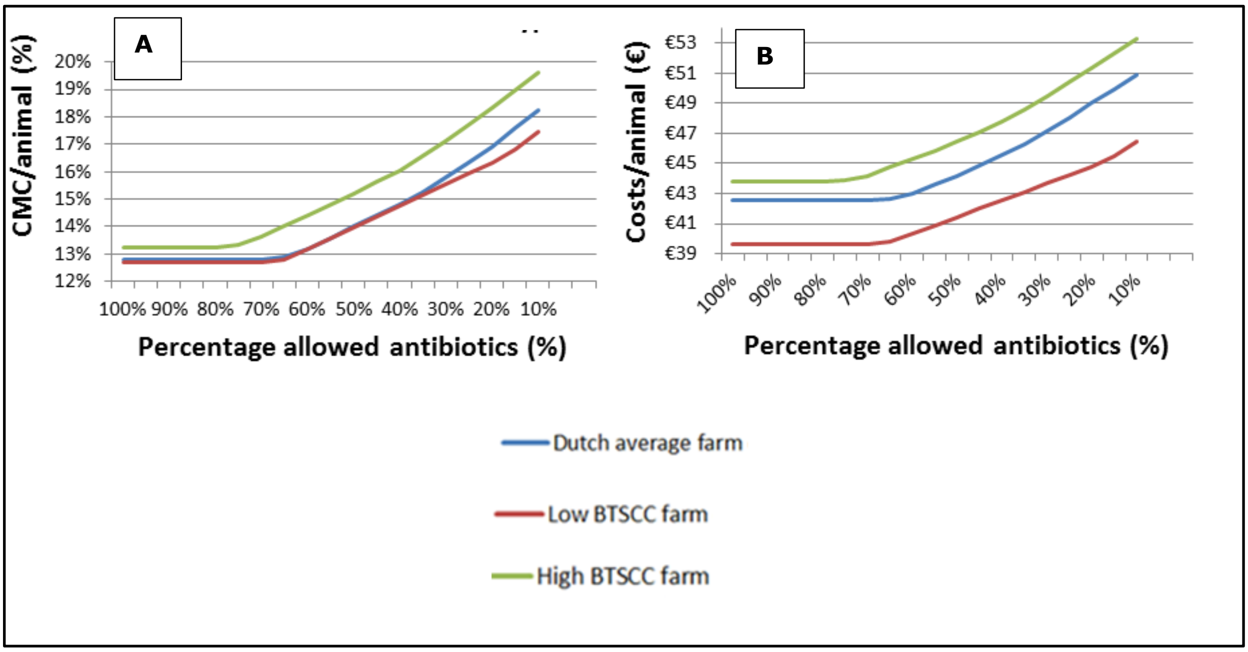

Figure 1. The effect of antibiotic restriction on the clinical mastitis cases (A) and economic costs (B) for a Dutch average-, high BTSCC- and low BTSCC farm.

Due to the restriction in the allowable amount of antibiotics used, the linear programming model tries to find the optimal distribution of the animals in the groups over the choice whether or not to use dry cow antibiotics. Till the moment where the allowed antibiotic use isn't restricted, the distribution of the animals stays the same for all three types of farms.
For the Dutch average farm the first change in the animal distribution starts at an antibiotic use of 65% the first group which changes from antibiotic use to no antibiotic use at drying off are the heifers with a SCC between 100,000-150,000 cells/mL. The next groups that will shift are subsequently cows SCC 0-50,000 cells/mL, cows SCC 150,000-250,000 cells/mL, cows SCC 100,000-150,000 cells/mL and cows SCC 50,000-100,000 cells/mL. Interesting to see is that both groups of heifers SCC 0-50,000 cells/mL and SCC 50,000-100,000 cell/mL do not shift at all (table 4.3).

Table 4.3 Distribution of the animals over the use of antibiotics at drying off on a Dutch average farm.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	6		4		4		5		2		5		5	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
95%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
90%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
85%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
80%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
75%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
70%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
65%	0	6	4	0	0	4	5	0	1	1	5	0	5	0
60%	0	6	3	1	0	4	5	0	0	2	5	0	5	0
55%	0	6	1	2	0	4	5	0	0	2	5	0	5	0
50%	0	6	0	4	0	4	5	0	0	2	5	0	5	0
45%	0	6	0	4	0	4	5	0	0	2	5	0	3	2
40%	0	6	0	4	0	4	5	0	0	2	5	0	2	4
35%	0	6	0	4	0	4	5	0	0	2	5	0	0	5
30%	0	6	0	4	0	4	5	0	0	2	3	2	0	5
25%	0	6	0	4	0	4	5	0	0	2	1	4	0	5
20%	0	6	0	4	0	4	5	1	0	2	0	5	0	5
15%	0	6	0	4	0	4	3	2	0	2	0	5	0	5
10%	0	6	0	4	0	4	1	4	0	2	0	5	0	5

For the high BTSCC farm the first change in the animal distribution starts at an antibiotic use of 65%. The first group which changes from antibiotic use to no antibiotic use at drying off are the heifers with a SCC between 100,000-150,000 cells/mL. The next groups which will shift are subsequently cows SCC 0-50,000 cells/mL, cows SCC 150,000-250,000 cells/mL, cows SCC 100,000-150,000 cells/mL and cows SCC 50,000-100,000 cells/mL. Interesting to see it that both groups of heifers SCC 0-50,000 cells/mL and SCC 50,000-100,000 cell/mL do not shift at all (table 4.4).

Table 4.4 Distribution of the animals over the use of antibiotics at drying off on a high BTSCC farm.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	2		4		3		5		2		3		3	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
95%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
90%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
85%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
80%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
75%	0	2	4	0	0	3	5	0	1	1	3	0	3	0
70%	0	2	4	0	0	3	5	0	0	2	3	0	3	0
65%	0	2	3	1	0	3	5	0	0	2	3	0	3	0
60%	0	2	2	2	0	3	5	0	0	2	3	0	3	0
55%	0	2	1	4	0	3	5	0	0	2	3	0	3	0
50%	0	2	0	4	0	3	5	0	0	2	3	0	3	0
45%	0	2	0	4	0	3	5	0	0	2	3	0	1	2
40%	0	2	0	4	0	3	5	0	0	2	3	0	0	3
35%	0	2	0	4	0	3	5	0	0	2	2	1	0	3
30%	0	2	0	4	0	3	5	0	0	2	1	2	0	3
25%	0	2	0	4	0	3	4	0	0	2	0	3	0	3
20%	0	2	0	4	0	3	3	2	0	2	0	3	0	3
15%	0	2	0	4	0	3	2	3	0	2	0	3	0	3
10%	0	2	0	4	0	3	1	4	0	2	0	3	0	3

For the low BTSCC farm the first change in the animal distribution starts at an antibiotic use of 60% the first group which changes from antibiotic use to no antibiotic use at drying off are the cows with a SCC 0-50,000 cells/mL. The next groups which will shift are subsequently cows SCC 150,000-250,000 cells/mL, cows SCC 100,000-150,000 cells/mL and cows SCC 50,000-100,000 cells/mL. Interesting to see it that both groups of heifers SCC 0-50,000 cells/mL and SCC 50,000-100,000 cell/mL do not shift at all (table 4.5).
The subsequent between the three types of farms is in general the same, but the shifts are all appear on a different level of amount in antibiotic restriction.

Table 4.5 Distribution of the animals over the use of antibiotics at drying off on a low BTSCC farm.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	12		22		2		4		0		1		1	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
95%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
90%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
85%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
80%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
75%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
70%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
65%	0	12	21	0	0	2	4	0	0	0	1	0	1	0
60%	0	12	19	3	0	2	4	0	0	0	1	0	1	0
55%	0	12	17	5	0	2	4	0	0	0	1	0	1	0
50%	0	12	15	7	0	2	4	0	0	0	1	0	1	0
45%	0	12	12	9	0	2	4	0	0	0	1	0	1	0
40%	0	12	10	12	0	2	4	0	0	0	1	0	1	0
35%	0	12	8	14	0	2	4	0	0	0	1	0	1	0
30%	0	12	5	16	0	2	4	0	0	0	1	0	1	0
25%	0	12	3	19	0	2	4	0	0	0	1	0	1	0
20%	0	12	1	21	0	2	4	0	0	0	1	0	1	0
15%	0	12	0	22	0	2	4	0	0	0	0	1	0	1
10%	0	12	0	22	0	2	2	3	0	0	0	1	0	1

Increasing and decreasing risk

When the risk for clinical mastitis decreases by 10% almost the same differences appear as in the default situation. The point of inflection remains the same for all three types of farms, around 70% for the high BTSCC farm and between 60-65% for the other two types of farms. Also the chance for a clinical mastitis becomes steeper upon 30% (figure 2). The underlying results of figure 2 can be found in appendix 3.

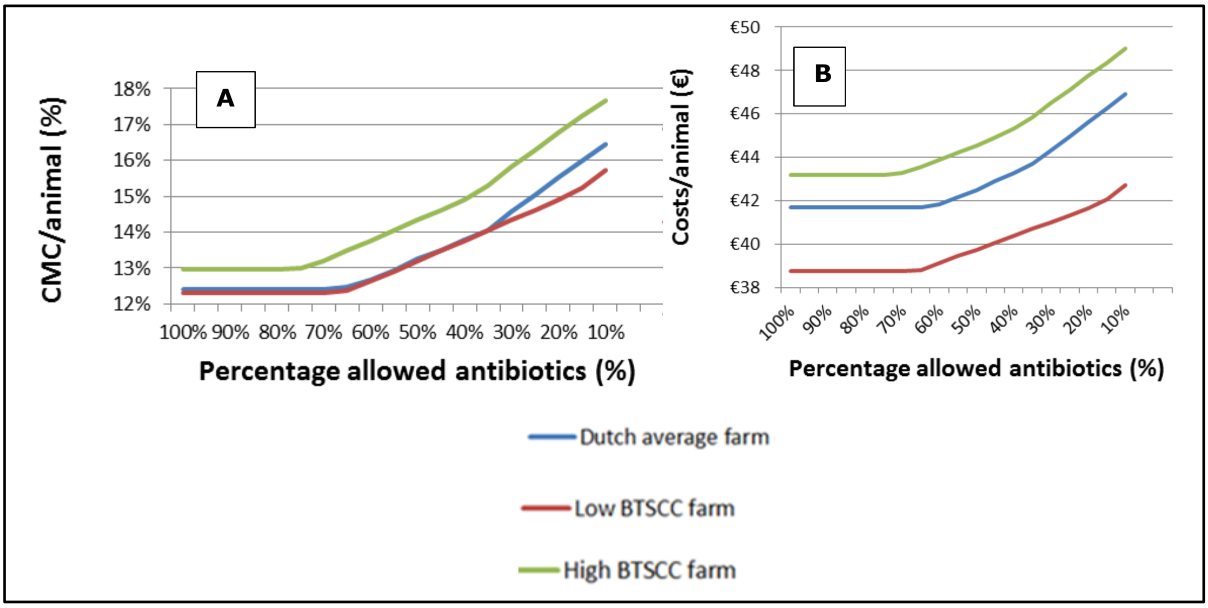

Figure 2. The effect of antibiotic restriction on the clinical mastitis cases (A) and economic costs (B) for a Dutch average-, high BTSCC- and low BTSCC farm with 10% less clinical mastitis risk.

For the Dutch average farm the first change in the animal distribution starts at an antibiotic use of 65% the first group which changes from antibiotic use to no antibiotic use at drying off are the heifers with a SCC between 100,000-150,000 cells/mL. the next groups which will shift are subsequently cows SCC 0-50,000 cells/mL, cows SCC 150,000-250,000 cells/mL, cows SCC 50,000-100,000 cells/mL and cows SCC 100,000-150,000 cells/mL. Interesting to see it that both groups of heifers SCC 0-50,000 cells/mL and SCC 50,000-100,000 cell/mL don't shift at all. (appendix 4.)

For the high BTSCC farm the subsequent is almost the same, only two cow groups are different (appendix 5). For the low BTSCC farm cows with a SCC 0-50,000 cells/mL are shifting first and the other three cow groups are shifting on the same time afterwards (appendix 6).

When the risk for clinical mastitis increases by 10%, almost the same differences appears as in the default situation. The point of inflection remains the same for all three types of farms, around 70% for the high BTSCC farm and between 60-65% for the other two types of farms. Also the chance for an clinical mastitis becomes steeper upon 30% (figure 3.). The underlying results of figure 3 can be found in appendix 7.

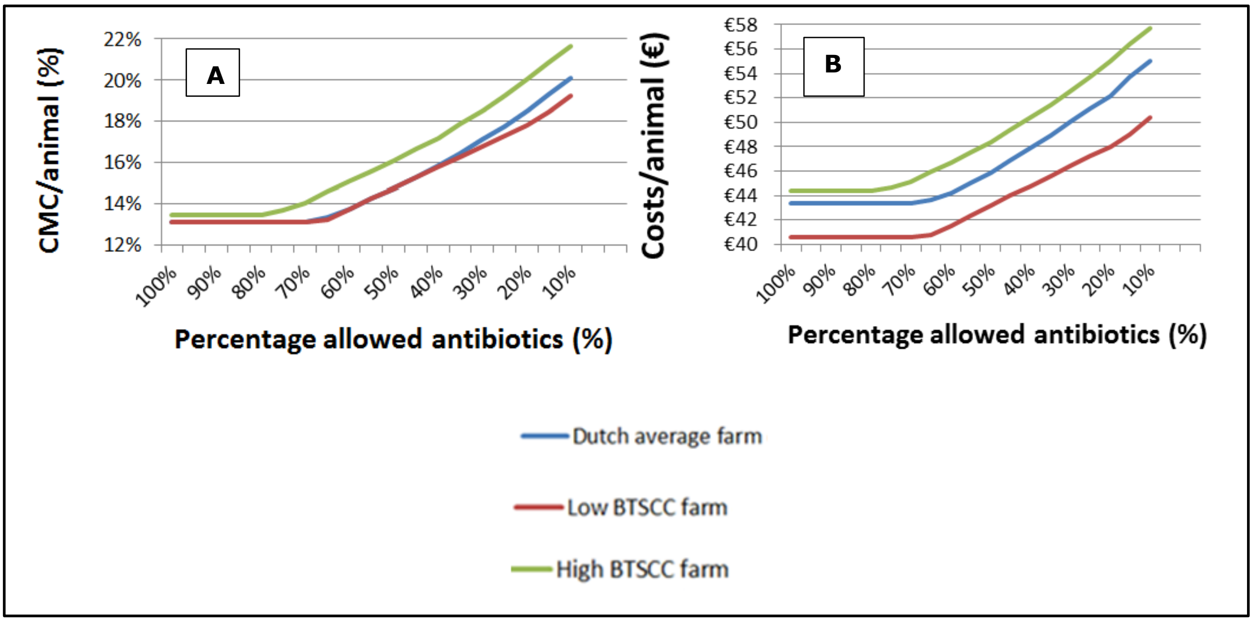

Figure 3. The effect of antibiotic restriction on the clinical mastitis cases (A) and economic costs (B) for a Dutch average-, high BTSCC- and low BTSCC farm with 10% more clinical mastitis risk.

For the Dutch average farm, the first change in the animal distribution starts at an antibiotic use of 65% the first group which changes from antibiotic use to no antibiotic use at drying off are the heifers with a SCC between 100,000-150,000 cells/mL. The next groups which shifts are subsequently cows SCC 0-50,000 cells/mL, cows SCC 150,000-250,000 cells/mL, cows SCC 100,000-150,000 cells/mL and cows SCC 50,000-100,000 cells/mL. Interesting to see it that both groups of heifers SCC 0-50,000 cells/mL and SCC 50,000-100,000 cell/mL don't shift at all. (appendix 8.)

For the high BTSCC farm the subsequent is almost the same compared to the Dutch average farm, only two cow groups shifts different (appendix 9). For the low BTSCC farm cows with a SCC 0-50,000 cells/mL are shifting first and the other three cow groups are shifting on the same time afterwards (appendix 10).

5. Discussion

Over the years a lot of research has been done on dynamics of IMI and mastitis management which was reviewed in a meta-analysis with about 30 different studies by (Halasa et al., 2009d); (Halasa et al., 2009c). The use and effect of antibiotics at drying off are investigated quite often. Cows treated with antibiotics at drying off had less clinical mastitis as compared to untreated cows e.g. (Schukken et al., 1993); (Bradley and Green, 2000).

Selective dry cow therapy was introduced to avoid the unnecessarily use of antibiotics in quarters of cows that are not infected. Different studies about SDCT produced positive results (Osterås et al., 1991); (Berry and Hillerton, 2002b); (Robert et al., 2006). In a study done by Halasa et al., (Halasa et al., 2009d) it was shown that SDCT gives a higher protection against new IMI compared to no DCT and BDCT showed more protection when compared to SDCT.

The costs around mastitis are also investigated. Although the variation is big, it is clear that mastitis has a major economic impact on a dairy farm ((Schepers and Dijkhuizen, 1991); (Halasa et al., 2007); (Hogeveen et al., 2011).

Although the economic costs of mastitis are investigated in several studies, the economic effect of different DCT are less investigated.
There are three published studies which dealt with economic costs of mastitis and different DCT recently ((Berry et al., 2004); (Halasa et al., 2007); (Huijps and Hogeveen, 2007)). The objective, methods used and outcomes of these studies all differ from each other.

(Berry et al., 2004) , used a decision tree analysis to help decision making at individual cow level. This was done because of the practical need for decision making on different dry cow strategies. During the study different strategies were considered either, total dry cow treatment, the use of teat seal or no dry cow treatment. The physiological impacts and relative costs of these strategies were evaluated. It was concluded that dry cow antibiotics remains a cost-effective measure compared with no treatment at drying off and the benefits of dry cow therapy vary according to the infection status of the cow (Berry et al., 2004).

(Huijps and Hogeveen, 2007) created a stochastic Monte Carlo model to simulate the dynamics of intramammary infections (IMI) around the dry period to predict the economic consequences of DCT around the dry period for different types of pathogens. They found average costs per cow of €15.60 for blanket DCT, €13.72 for selective DCT and €18.02 for no DCT all with large variation within the treatment groups. Due to this large variation the treatment to choose depends toward the willingness to take risk for a farmer. BDCT gives the smallest risk .
(Huijps and Hogeveen, 2007) stated that a farmer willing to take more risks and wanting the lowest DCT costs will choose SDCT. But in that situation the farmer risks having high costs compared to blanked DCT. The selection criteria for the selective DCT were not investigated.

A bio economic model was built to improve cost assessment of IMI as an important prerequisite to economic assessment of IMI control strategies (Halasa et al., 2009b); (Halasa et al., 2010a). The model is a useful tool to calculate the economic effects of IMI control and will be helpful for decision making. A specific important point in the study done by Halasa is the dynamics of transmission of IMI between cows which is realistic on farm level.

A model to calculate the economic losses of mastitis was developed by Huijps, (Huijps et al., 2008). The model was developed as tool for farmers and advisors to calculate the economic costs of mastitis per farm. The model was also used to investigate the economic effects of different management tools toward mastitis management ((Huijps et al., 2010).

All studies differ and because of the variations between the studies it is hard to give a general conclusion about the economic costs of mastitis and DCT.
It is also hard to compare the results of these studies to the results of this study. The studies mentioned above have the limitations that they only calculate certain situations or scenarios and do not solve for optimum solutions. Therefore this study is the first which uses optimization to find the optimal selection criteria for SDCT.
Uninfected cows at drying off were less likely to acquire new infections (WOOLFORD et al., 2001); (Berry et al., 2003). For this reason low SCC animals are used in the model only. In the other studies the economic costs are calculated for the whole herd which makes it difficult to compare the results.

The duration of the study also differ between the studies which causes variation.
Due to the antibiotic restriction which is mandatory in the Netherlands this is the first research which calculated the effects on IMI cases, economics and optimal animal selection criteria at different antibiotics levels. This study is important to see the effects and give indications for a proper management within the frameworks of antibiotic restriction.

Therefore, this research is unique on the optimisation methodology of DCT and mastitis management.

The optimisation methodology will help dairy farmers to manage mastitis by the dry cow therapy when the use of antibiotics in a preventive way is restricted. Due to the overview of the economic costs, dairy farmers will get more affinity on mastitis and dry cow therapy management like selective dry cow therapy.

One major point it this study is the choice for an economic model rather than a bio economic model. When a quarter was infected it was excluded from the study, so no data for the cure rate of an existing IMI and also next infection chance were used which makes the model more fixed. In a bio economic model the dynamics of mastitis are followed over a period. When using a bio economic model, these IMI dynamics are closer to the reality which makes the data and results more useful in practice. Due to the available dataset this was impossible.

It should be interesting to follow the animals for a longer period of time, for example a couple of lactations. Due to the restriction of antibiotics at drying off, more mastitis cases will occur which will lead to different selection criteria in the next year. When following the animals for a longer period the relationship between the economic cost and the years will become more clear.

Due to the design of the study, inclusion of only the low SCC animals, the model does not give the economic figures of a whole herd which is of interest for dairy farmers and makes it harder to translate the results towards the effects on farm level. But the data used in this study can be justified by the research done by the GD. When including high SCC animals in the model will required assumptions which makes the results less powerful. Next to that SDCT will only be applied on low SCC animals which was one of the main question during this study. Therefore heifers in their first lactation were not included in the model also. A next step therefore is to expand the model, with high SCC animals, toward a model which is useful at the whole farm level.

The animals in the model were distributed over seven different groups based on the SCC on the MPR results. Each group has a range over 50,000 cells/mL. But for group seven the range was 100,000. Next time the range per groups should be 50,000 cells/mL for each group.

The available dataset was based on a split udder design which gives data at quarter level. A split udder design will have positive points, like cow and management factors are the same for each treatment. For the model data at cow levels were included which were calculated from the data at quarter level. Due to the split udder design only two quarters per treatment were used which can cause an underestimation of the mastitis cases when interdependence between quarts exist (Berry and Meaney, 2006). This could affect the results a little bit, but won't be that big.

Animals were followed during the dry period and the first 100 DIM. Therefore, it is hard to compare the amount of antibiotics used to the total amount of antibiotics used for a whole herd for all diseases rather than only mastitis.
It was assumed that animals which were infected with an IMI were treated with antibiotics in the teat only. Some farmers are using intramuscular antibiotics as well and some farmers treat high SCC which are not treated in this study.

In some of the scenarios it was assumed that the chance for a clinical mastitis was increased and decreased by 10% when no antibiotics were used at drying off. It the study it was assumed that the chance for subclinical mastitis remained the same. This will leads to an over- and underestimation of the costs. Because this assumption was made at all different farm types the differences are the same.

In the optimization phase the use of teat seal is not included because the effects of teat sealant with and without the use of antibiotics at drying off are not clear enough. In the future the use of teat sealant will increase because it can be a proper management aspect next to SDCT. Therefore the effect of teat seal should be investigated properly prior to expand the model toward the use of teat sealant.

During each research interesting new points will appear which are interesting but are not used in the research because of the lack of time etc.

The data which are used for the (sub)clinical mastitis chances are based on only one, the last milk recording results before drying off. At the end of a lactation the milk production decreases which will increase the SCC a bit (Concha, 1986). This could have an effect on the relationship between the SCC and the pathogen level in the milk. So maybe this increase of the SCC will overestimate the IMI risk. Therefore it is interesting to do more research on the effect of using more MPR results on the IMI risk. Maybe also the clinical mastitis history during the last lactation of the animal can be used. by this way it can be investigated if the current selection criteria is sufficient.

The use of the SCC for the decision point is an easy and cheap method. But the SCC only gives an indication about the presence of an IMI or the presence of pathogens. Due to the dilution effect of the four quarters the danger can be minimized. The use of a bacterial research at drying off will give more knowledge of the presences of different pathogens in the udder.
As a next step a more appropriate antibiotic at drying off can be used which will reduce the risk for mastitis. The extra costs for the bacterial research should be included in the model and also the decreased risks for mastitis. The use of teat sealant at drying off will be included in the model on the same way. The model can be expand by all kind of other researches and data, for example management factors.

A first step is made by developing the model, in which scientific data are used and translated, toward a practical tool for dairy farmers. The tool can help dairy farmers with mastitis management within the frameworks of antibiotic restriction. In the future this model should be expanded towards a total farm based tool. Therefore different subjects are important e.g. inclusion of high SCC cows, mastitis dynamics during the whole lactation, antibiotic use for treatment, treatment rate and all other subjects which influence mastitis management.

6. Conclusion

This study showed that there is a difference between heifers and cows in terms of mastitis dynamics and DCT. Each animal, heifer or cow have their own optimal selection criteria based on the SCC at drying off when antibiotics are restricted.

The use of antibiotics at drying off reduce the risk for a (sub)clinical mastitis. But not all the animals on a dairy farm needs antibiotics at drying off in a preventive way.
When the management around DCT is optimal, between 30 and 35% of the antibiotics used at drying off do not have a reducing effect on the amount of mastitis cases and therefore increase the economic costs of DCT unnecessary. Because of the low costs of antibiotics and the high costs of mastitis the use of antibiotics is applied a lot in practice to reduce the risk for a mastitis case and the associated high economic costs.

On a low BTSCC farm, more animals with lower economics costs are present compared to a Dutch average farm and a high BTSCC farm. Therefore low BTSCC farms have in general the lowest economic costs of mastitis management.
Due to a higher number of animals with a low SCC the economic risk for SDCT is lower and easier to control on a low BTSCC farm.

Based on lowest economic costs of mastitis the use of teat sealant will cause a change on the selected animals for SDCT from no antibiotics used at heifers with a SCC<150.000 to no antibiotics used at heifers with a SCC<150.000 and cows with a SCC<50.000

Acknowledgements

I want to thank Theo Lam, Henk Hogeveen and Christian Scherpenzeel to give me the opportunity to do this interesting and great thesis at the GD Deventer in corporation with the Business Economic Group of Wageningen UR. The past four months I have learned a lot about mastitis and dry cow therapy. But the most important thing I have learned is to think in a more critically and analytical way.
During the thesis Christian Scherpenzeel and Henk Hogeveen supported me with all the things I have dealt with and challenged me to fulfil the study the way it is done.
I also want to give some attention to Paul Berentsen of the Business Economic Group of Wageningen UR who helped me with all the things around the linear programming model.
Ingrid den Uijl of the GD Deventer helped me during the thesis by given me the input which I needed and made me think about these data. Thank you for that.

I want to end with the statement which Christian Scherpenzeel told me, a good research will give you more questions than you can answer. But I hope that I have answered the right questions to fulfil this thesis.

Thank you all.

References

AMRO, A. 2011. Vrije zuivelmarkt, bedreiging of kans? Strategie op weg naar 2020.
Barbano, D. M., Y. Ma, and M. V. Santos. 2006. Influence of raw milk quality on fluid milk shelf life. Journal of dairy science 89 Suppl 1:E15-19.
Berry, D. P. and W. J. Meaney. 2006. Interdependence and distribution of subclinical mastitis and intramammary infection among udder quarters in dairy cattle. Preventive veterinary medicine 75(1–2):81-91.
Berry, E. A. and J. E. Hillerton. 2002a. The Effect of an Intramammary Teat Seal on New Intramammary Infections. Journal of dairy science 85(10):2512-2520.
Berry, E. A. and J. E. Hillerton. 2002b. The Effect of Selective Dry Cow Treatment on New Intramammary Infections. Journal of dairy science 85(1):112-121.
Berry, E. A. and J. E. Hillerton. 2002c. The effect of selective dry cow treatment on new intramammary infections. Journal of dairy science 85(1):112-121.
Berry, E. A., H. Hogeveen, and J. E. Hillerton. 2004. Decision tree analysis to evaluate dry cow strategies under UK conditions. Journal of Dairy Research 71(04):409-418.
Berry, E. A., W. T. Johnston, and J. E. Hillerton. 2003. Prophylactic Effects of Two Selective Dry Cow Strategies Accounting for Interdependence of Quarter. Journal of dairy science 86(12):3912-3919.
Bradley, A. J., J. E. Breen, B. Payne, P. Williams, and M. J. Green. 2010. The use of a cephalonium containing dry cow therapy and an internal teat sealant, both alone and in combination. Journal of dairy science 93(4):1566-1577.
Bradley, A. J. and M. J. Green. 2000. A study of the incidence and significance of intramammary enterobacterial infections acquired during the dry period. Journal of dairy science 83(9):1957-1965.
Bradley, A. J. and M. J. Green. 2001. An Investigation of the Impact of Intramammary Antibiotic Dry Cow Therapy on Clinical Coliform Mastitis. Journal of dairy science 84(7):1632-1639.
Concha, C. 1986. Cell types and their immunological functions in bovine mammary tissues and secretions--a review of the literature. Nordisk veterinaermedicin 38(5):257-272.
Den Uijl, I., C. Scherpenzeel, J. Keurentjens, G. Van Schaik, and T. J. Lam. 2012. Eindrapportage selectief droogzetten van melkvee.
diergeneeskunde, K. N. M. v. 2013. Richtlijn antimicrobiële middelen bij het droogzetten van melkkoeien versie 1.0. Page 41.

.
Dodd, F. H., D. R. Westgarth, F. K. Neave, and R. G. Kingwill. 1969. Mastitis--the strategy of control. Journal of dairy science 52(5):689-695.
Eberhart, R. J. 1986. Management of Dry Cows to Reduce Mastitis1. Journal of dairy science 69(6):1721-1732.
Halasa, T., K. Huijps, O. Østerås, and H. Hogeveen. 2007. Economic effects of bovine mastitis and mastitis management: A review. Veterinary Quarterly 29(1):18-31.
Halasa, T., M. Nielen, A. P. W. De Roos, R. Van Hoorne, G. de Jong, T. J. G. M. Lam, T. van Werven, and H. Hogeveen. 2009a. Production loss due to new subclinical mastitis in Dutch dairy cows estimated with a test-day model. Journal of dairy science 92(2):599-606.
Halasa, T., M. Nielen, R. B. M. Huirne, and H. Hogeveen. 2009b. Stochastic bio-economic model of bovine intramammary infection. Livestock Science 124(1–3):295-305.
Halasa, T., M. Nielen, T. van Werven, and H. Hogeveen. 2010a. A simulation model to calculate costs and benefits of dry period interventions in dairy cattle. Livestock Science 129(1–3):80-87.
Halasa, T., M. Nielen, T. van Werven, H. Hogeveen, T. Hisham Beshara Halasa, M. Nielen, T. van Werven, and H. Hogeveen. 2010b. A simulation model to calculate costs and benefits of dry period interventions in dairy cattle. Livestock Science 129:80.
Halasa, T., M. Nielen, A. C. Whist, and O. Osteras. 2009c. Meta-analysis of dry cow management for dairy cattle. Part 2. Cure of existing intramammary infections. Journal of dairy science 92(7):3150-3157.
Halasa, T., O. Osteras, H. Hogeveen, T. van Werven, and M. Nielen. 2009d. Meta-analysis of dry cow management for dairy cattle. Part 1. Protection against new intramammary infections. Journal of dairy science 92(7):3134-3149.
Hogeveen, H., K. Huijps, and T. J. Lam. 2011. Economic aspects of mastitis: new developments. New Zealand veterinary journal 59(1):16-23.
Huijps, K. and H. Hogeveen. 2007. Stochastic Modeling to Determine the Economic Effects of Blanket, Selective, and No Dry Cow Therapy. Journal of dairy science 90(3):1225-1234.
Huijps, K., H. Hogeveen, T. J. G. M. Lam, and A. G. J. M. Oude Lansink. 2010. Costs and efficacy of management measures to improve udder health on Dutch dairy farms. Journal of dairy science 93(1):115-124.
Huijps, K., T. J. Lam, and H. Hogeveen. 2008. Costs of mastitis: facts and perception. Journal of Dairy Research 75(01):113-120.
Kemp, M. H., A. M. Nolan, P. J. Cripps, and J. L. Fitzpatrick. 2008. Animal-based measurements of the severity of mastitis in dairy cows. Veterinary Record 163(6):175-179.
Lam, T. J., B. H. van den Borne, J. Jansen, K. Huijps, J. C. van Veersen, G. van Schaik, and H. Hogeveen. 2013. Improving bovine udder health: a national mastitis control program in the Netherlands. Journal of dairy science 96(2):1301-1311.
Neave, F. K., F. H. Dodd, R. G. Kingwill, and D. R. Westgarth. 1969. Control of mastitis in the dairy herd by hygiene and management. Journal of dairy science 52(5):696-707.

Norton, P. B. R. H. a. R. D. 1986. Mathematical programming for economic analysis in agraculture. Mac Millan publishing company, New York.
Osterås, O., L. Sandvik, J. Aursjø, G. G. Gjul, and A. Jørstad. 1991. Assessment of strategy in selective dry cow therapy for mastitis control. Zentralblatt fur Veterinarmedizin. Reihe B. Journal of veterinary medicine. Series B 38(7):513-522.
Rabiee, A. R. and I. J. Lean. 2013. The effect of internal teat sealant products (Teatseal and Orbeseal) on intramammary infection, clinical mastitis, and somatic cell counts in lactating dairy cows: A meta-analysis. Journal of dairy science 96(11):6915-6931.
Robert, A., H. Seegers, and N. Bareille. 2006. Incidence of intramammary infections during the dry period without or with antibiotic treatment in dairy cows - A quantitative analysis of published data. Veterinary Research 37(1):25-48.
Ruegg, P. L. and T. J. Tabone. 2000. The Relationship Between Antibiotic Residue Violations and Somatic Cell Counts in Wisconsin Dairy Herds. Journal of dairy science 83(12):2805-2809.
Schepers, J. A. and A. A. Dijkhuizen. 1991. The economics of mastitis and mastitis control in dairy cattle: a critical analysis of estimates published since 1970. Preventive veterinary medicine 10(3):213-224.
Schukken, Y. H., J. Vanvliet, D. Vandegeer, and F. J. Grommers. 1993. A randomized blind trial on dry cow antibiotic infusion in a low somatic cell count herd. Journal of dairy science 76(10):2925-2930.
Schukken, Y. H., D. J. Wilson, F. Welcome, L. Garrison-Tikofsky, and R. N. Gonzalez. 2003. Monitoring udder health and milk quality using somatic cell counts. Vet. Res. 34(5):579-596.
St.Rose, S. G., J. M. Swinkels, W. D. Kremer, C. L. Kruitwagen, and R. N. Zadoks. 2003. Effect of penethamate hydriodide treatment on bacteriological cure, somatic cell count and milk production of cows and quarters with chronic subclinical Streptococcus uberis or Streptococcus dysgalactiae infection. Journal of Dairy Research 70(04):387-394.
WOOLFORD, M. W., J. H. WILLIAMSON, T. M. DAY, S. J. LACY-HULBERT, and H. V. HENDERSON. 2001. Effect of localised antibiotic infusions applied to the teat-canal and teat sinus at drying-off on mastitis in the dry-period and at calving. Journal of Dairy Research 68(04):551-558.

Appendix 1

Costs per animal, number of clinical mastitis cases and antibiotic use per animal in percentages based on scenario no. 1. Where antibiotics were used on all animals on a Dutch average farm.

Scenario no.	Situation	Costs per animal (%)	Number of clinical mastitis cases (%)	Antibiotic use per animal (%)
Dutch average farm				
1.	AB on all animals	100.00	100.00	100.00
2.	No AB on SCC <100,000	106.25	127.95	42.12
3.	No AB on SCC <50,000	100.30	110.00	70.26
4.	No AB on heifer SCC <150,000	97.25	106.92	63.31
5.	No AB on heifer SCC <150,000 cows SCC <50,000	100.07	114.10	52.16
6.	No AB on all low SCC animals	117.32	153.08	6.74
7.	AB on all animals + teat seal	124.77	100.00	100.00
8.	No AB on SCC <100,000 + teat seal	115.93	103.59	40.98
9.	No AB on SCC <50,000 + teat seal	118.43	99.23	69.78
10.	No AB on heifer SCC <150,000 + teat seal	115.25	96.15	62.83
11.	No AB on heifer SCC <150,000 cows SCC <50,000 + teat seal	114.66	97.69	51.43
12.	No AB on all low SCC animals+ teat seal	115.59	110.26	4.85

Costs per animal, number of clinical mastitis cases and antibiotic use per animal in percentages based on scenario no. 13. Where antibiotics were used on all animals on a high BTSCC farm.

Scenario no.	Situation	Costs per animal (%)	Number of clinical mastitis cases (%)	Antibiotic use per animal (%)
High BTSCC farm				
13.	AB on all animals	100.00	100.00	100.00
14.	No AB on SCC <100,000	111.04	134.94	38.63
15.	No AB on SCC <50,000	103.28	113.38	70.08
16.	No AB on heifer SCC <150,000	98.53	105.95	70.80
17.	No AB on heifer SCC <150,000 cows SCC <50,000	103.24	117.47	51.78
18.	No AB on all low SCC animals	120.35	156.13	7.07
19.	AB on all animals + teat seal	124.35	100.00	100.00
20.	No AB on SCC <100,000 + teat seal	117.92	107.06	37.36
21.	No AB on SCC <50,000 + teat seal	120.06	101.12	69.53
22.	No AB on heifer SCC <150,000 + teat seal	117.36	97.03	70.41
23.	No AB on heifer SCC <150,000 cows SCC <50,000 + teat seal	116.38	99.63	50.96
24.	No AB on all low SCC animals+ teat seal	117.34	112.64	5.10

Costs per animal, number of clinical mastitis cases and antibiotic use per animal in percentages based on scenario no. 25. Where antibiotics were used on all animals on a low BTSCC farm.

Scenario no.	Situation	Costs per animal (%)	Number of clinical mastitis cases (%)	Antibiotic use per animal (%)
Low BTSCC farm				
25.	AB on all animals	100.00	100.00	100.00
26.	No AB on SCC <100,000	112.91	146.35	9.48
27.	No AB on SCC <50,000	108.93	135.50	24.43
28.	No AB on heifer SCC <150,000	95.75	105.52	66.30
29.	No AB on heifer SCC <150,000 cows SCC <50,000	108.61	136.69	18.25
30.	No AB on all low SCC animals	113.87	148.52	6.41
31.	AB on all animals + teat seal	126.30	100.00	100.00
32.	No AB on SCC <100,000 + teat seal	113.51	106.31	7.75
33.	No AB on SCC <50,000 + teat seal	114.62	103.55	23.05
34.	No AB on heifer SCC <150,000 + teat seal	115.83	95.86	65.89
35.	No AB on heifer SCC <150,000 cows SCC <50,000 + teat seal	113.17	102.76	16.78
36.	No AB on all low SCC animals+ teat seal	113.46	106.90	4.61

Appendix 2

Summarized output of the Dutch average farm. With allowable and used antibiotic use, economic costs, (sub)clinical mastitis cases.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	135.72	4.24	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
95%	128.94	4.03	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
90%	122.15	3.82	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
85%	115.37	3.61	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
80%	108.58	3.39	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
75%	101.79	3.18	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
70%	95.01	2.97	42.53	4.09	12.78%	4.16	13.00%	91.49	2.86
65%	88.22	2.76	42.65	4.12	12.88%	4.24	13.25%	88.22	2.76
60%	81.43	2.54	43.02	4.22	13.19%	4.41	13.78%	81.43	2.54
55%	74.65	2.33	43.58	4.35	13.59%	4.58	14.31%	74.65	2.33
50%	67.86	2.12	44.18	4.48	14.00%	4.77	14.91%	67.86	2.12
45%	61.08	1.91	44.87	4.61	14.41%	5.00	15.63%	61.08	1.91
40%	54.29	1.70	45.56	4.74	14.81%	5.24	16.38%	54.29	1.70
35%	47.50	1.48	46.27	4.88	15.25%	5.46	17.06%	47.50	1.48
30%	40.72	1.27	47.17	5.05	15.78%	5.62	17.56%	40.72	1.27
25%	33.93	1.06	48.07	5.23	16.34%	5.79	18.09%	33.93	1.06
20%	27.14	0.85	49.00	5.42	16.94%	5.92	18.50%	27.14	0.85
15%	20.36	0.64	49.97	5.63	17.59%	6.01	18.78%	20.36	0.64
10%	13.57	0.42	50.95	5.83	18.22%	6.11	19.09%	13.57	0.42

Summarized output of the high BTSCC farm. With allowable and used antibiotic use, economic costs, (sub)clinical mastitis cases.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	89.07	4.24	€ 43.78	2.78	13.24%	2.71	12.90%	69.06	3.29
95%	84.62	4.03	€ 43.78	2.78	13.24%	2.71	12.90%	69.06	3.29
90%	80.16	3.82	€ 43.78	2.78	13.24%	2.71	12.90%	69.06	3.29
85%	75.71	3.61	€ 43.78	2.78	13.24%	2.71	12.90%	69.06	3.29
80%	71.26	3.39	€ 43.78	2.78	13.24%	2.71	12.90%	69.06	3.29
75%	66.80	3.18	€ 43.90	2.8	13.33%	2.77	13.19%	66.8	3.18
70%	62.35	2.97	€ 44.18	2.86	13.62%	2.88	13.71%	62.35	2.97
65%	57.90	2.76	€ 44.74	2.94	14.00%	2.99	14.24%	57.9	2.76
60%	53.44	2.54	€ 45.30	3.03	14.43%	3.11	14.81%	53.44	2.54
55%	48.99	2.33	€ 45.85	3.11	14.81%	3.22	15.33%	48.99	2.33
50%	44.53	2.12	€ 46.45	3.19	15.19%	3.35	15.95%	44.54	2.12
45%	40.08	1.91	€ 47.13	3.28	15.62%	3.5	16.67%	40.08	1.91
40%	35.63	1.70	€ 47.81	3.37	16.05%	3.65	17.38%	35.63	1.70
35%	31.17	1.48	€ 48.64	3.48	16.57%	3.77	17.95%	31.17	1.48
30%	26.72	1.27	€ 49.52	3.59	17.10%	3.88	18.48%	26.72	1.27
25%	22.27	1.06	€ 50.43	3.72	17.71%	3.97	18.90%	22.27	1.06
20%	17.81	0.85	€ 51.39	3.85	18.33%	4.03	19.19%	17.81	0.85
15%	13.36	0.64	€ 52.35	3.99	19.00%	4.09	19.48%	13.36	0.64
10%	8.91	0.42	€ 53.31	4.12	19.62%	4.15	19.76%	8.91	0.42

Summarized output of the low BTSCC farm. With allowable and used antibiotic use, economic costs, (sub)clinical mastitis cases.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	178.14	4.24	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
95%	169.23	4.03	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
90%	160.32	3.82	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
85%	151.42	3.61	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
80%	142.51	3.39	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
75%	133.60	3.18	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
70%	124.70	2.97	39.66	5.34	12.71%	3.72	8.86%	118.09	2.81
65%	115.79	2.76	39.76	5.37	12.79%	3.78	9.00%	115.79	2.76
60%	106.88	2.54	40.32	5.54	13.19%	4.01	9.55%	106.88	2.54
55%	97.98	2.33	40.88	5.7	13.57%	4.24	10.10%	97.98	2.33
50%	89.07	2.12	41.44	5.87	13.98%	4.47	10.64%	89.07	2.12
45%	80.16	1.91	42	6.04	14.38%	4.7	11.19%	80.16	1.91
40%	71.26	1.70	42.56	6.2	14.76%	4.93	11.74%	71.26	1.70
35%	62.35	1.48	43.12	6.37	15.17%	5.16	12.29%	62.35	1.48
30%	53.44	1.27	43.68	6.53	15.55%	5.39	12.83%	53.44	1.27
25%	44.53	1.06	44.24	6.7	15.95%	5.62	13.38%	44.53	1.06
20%	35.63	0.85	44.8	6.86	16.33%	5.85	13.93%	36.63	0.87
15%	26.72	0.64	45.52	7.06	16.81%	6.08	14.48%	26.72	0.64
10%	17.81	0.42	46.49	7.33	17.45%	6.2	14.76%	17.81	0.42

Appendix 3

Summarized output of the Dutch average farm with a 10% smaller infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	135.72	4.24	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
95%	128.94	4.03	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
90%	122.15	3.82	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
85%	115.37	3.61	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
80%	108.58	3.39	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
75%	101.79	3.18	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
70%	95.01	2.97	41.70	3.97	12.41%	4.16	13.00%	91.31	2.85
65%	88.22	2.76	41.71	3.99	12.47%	4.24	13.25%	88.22	2.76
60%	81.43	2.54	41.84	4.05	12.66%	4.40	13.75%	81.43	2.54
55%	74.65	2.33	42.16	4.14	12.94%	4.58	14.31%	74.65	2.33
50%	67.86	2.12	42.49	4.24	13.25%	4.76	14.88%	67.86	2.12
45%	61.08	1.91	42.89	4.32	13.50%	4.99	15.59%	61.08	1.91
40%	54.29	1.70	43.29	4.41	13.78%	5.22	16.31%	54.29	1.70
35%	47.50	1.48	43.69	4.50	14.06%	5.45	17.03%	47.50	1.48
30%	40.72	1.27	44.32	4.66	14.56%	5.54	17.31%	40.72	1.27
25%	33.93	1.06	44.96	4.81	15.03%	5.63	17.59%	33.93	1.06
20%	27.14	0.85	45.60	4.97	15.53%	5.73	17.91%	27.14	0.85
15%	20.36	0.64	46.26	5.12	16.00%	5.88	18.38%	20.36	0.64
10%	13.57	0.42	46.92	5.26	16.44%	6.04	18.88%	13.57	0.42

Summarized output of the high BTSCC farm with a 10% smaller infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	89.07	4.24	€ 43.19	2.72	12.95%	2.71	12.90%	68.97	3.28
95%	84.62	4.03	€ 43.19	2.72	12.95%	2.71	12.90%	68.97	3.28
90%	80.16	3.82	€ 43.19	2.72	12.95%	2.71	12.90%	68.97	3.28
85%	75.71	3.61	€ 43.19	2.72	12.95%	2.71	12.90%	68.97	3.28
80%	71.26	3.39	€ 43.19	2.72	12.95%	2.71	12.90%	68.97	3.28
75%	66.80	3.18	€ 43.20	2.73	13.00%	2.77	13.19%	66.8	3.18
70%	62.35	2.97	€ 43.26	2.77	13.19%	2.87	13.67%	62.35	2.97
65%	57.90	2.76	€ 43.57	2.83	13.48%	2.99	14.24%	57.9	2.76
60%	53.44	2.54	€ 43.88	2.89	13.76%	3.1	14.76%	53.44	2.54
55%	48.99	2.33	€ 44.20	2.95	14.05%	3.21	15.29%	48.99	2.33
50%	44.53	2.12	€ 44.53	3.01	14.33%	3.34	15.90%	44.53	2.12
45%	40.08	1.91	€ 44.92	3.07	14.62%	3.49	16.62%	40.08	1.91
40%	35.63	1.70	€ 45.31	3.13	14.90%	3.64	17.33%	35.63	1.70
35%	31.17	1.48	€ 45.86	3.21	15.29%	3.73	17.76%	31.17	1.48
30%	26.72	1.27	€ 46.49	3.32	15.81%	3.79	18.05%	26.72	1.27
25%	22.27	1.06	€ 47.11	3.42	16.29%	3.85	18.33%	22.27	1.06
20%	17.81	0.85	€ 47.74	3.52	16.76%	3.91	18.62%	17.81	0.85
15%	13.36	0.64	€ 48.38	3.62	17.24%	4	19.05%	13.36	0.64
10%	8.91	0.42	€ 49.02	3.71	17.67%	4.11	19.57%	8.91	0.42

Summarized output of the low BTSCC farm with a 10% smaller infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	178.14	4.24	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
95%	169.23	4.03	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
90%	160.32	3.82	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
85%	151.42	3.61	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
80%	142.51	3.39	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
75%	133.60	3.18	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
70%	124.70	2.97	38.77	5.17	12.31%	3.72	8.86%	117.84	2.81
65%	115.79	2.76	38.80	5.19	12.36%	3.77	8.98%	115.79	2.76
60%	106.88	2.54	39.12	5.31	12.64%	4.00	9.52%	106.88	2.54
55%	97.98	2.33	39.43	5.42	12.90%	4.23	10.07%	97.98	2.33
50%	89.07	2.12	39.75	5.54	13.19%	4.46	10.62%	89.07	2.12
45%	80.16	1.91	40.07	5.66	13.48%	4.69	11.17%	80.16	1.91
40%	71.26	1.70	40.38	5.78	13.76%	4.91	11.69%	71.26	1.70
35%	62.35	1.48	40.70	5.90	14.05%	5.14	12.24%	62.35	1.48
30%	53.44	1.27	41.01	6.02	14.33%	5.37	12.79%	53.44	1.27
25%	44.53	1.06	41.33	6.14	14.62%	5.60	13.33%	44.53	1.06
20%	35.63	0.85	41.65	6.26	14.90%	5.83	13.88%	35.63	0.85
15%	26.72	0.64	42.07	6.40	15.24%	6.04	14.38%	26.72	0.64
10%	17.81	0.42	42.70	6.61	15.74%	6.17	14.69%	17.81	0.42

Appendix 4

Distribution of the animals over the use of antibiotics at drying off on a Dutch average farm with a 10% smaller infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	6		4		4		5		2		5		5	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
95%	0	6	4	0	0	4	5	0	1	1	5	0	5	0
90%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
85%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
80%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
75%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
70%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
65%	0	6	4	0	0	4	5	0	1	1	5	0	5	0
60%	0	6	3	1	0	4	5	0	0	2	5	0	5	0
55%	0	6	1	2	0	4	5	0	0	2	5	0	5	0
50%	0	6	0	4	0	4	5	0	0	2	5	0	5	0
45%	0	6	0	4	0	4	5	0	0	2	5	0	3	2
40%	0	6	0	4	0	4	5	0	0	2	5	0	2	4
35%	0	6	0	4	0	4	5	0	0	2	5	0	0	5
30%	0	6	0	4	0	4	4	2	0	2	5	0	0	5
25%	0	6	0	4	0	4	2	3	0	2	5	0	0	5
20%	0	6	0	4	0	4	0	5	0	2	5	0	0	5
15%	0	6	0	4	0	4	0	5	0	2	3	2	0	5
10%	0	6	0	4	0	4	0	5	0	2	1	3	0	5

Appendix 5

Distribution of the animals over the use of antibiotics at drying off on a high BTSCC farm with a 10% smaller infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	2		4		3		5		2		3		3	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
95%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
90%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
85%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
80%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
75%	0	2	4	0	0	3	5	0	1	1	3	0	3	0
70%	0	2	4	0	0	3	5	0	0	2	3	0	3	0
65%	0	2	3	1	0	3	5	0	0	2	3	0	3	0
60%	0	2	2	2	0	3	5	0	0	2	3	0	3	0
55%	0	2	1	4	0	3	5	0	0	2	3	0	3	0
50%	0	2	0	4	0	3	5	0	0	2	3	0	3	0
45%	0	2	0	4	0	3	5	0	0	2	3	0	2	1
40%	0	2	0	4	0	3	5	0	0	2	3	0	0	3
35%	0	2	0	4	0	3	4	1	0	2	3	0	0	3
30%	0	2	0	4	0	3	3	2	0	2	3	0	0	3
25%	0	2	0	4	0	3	2	3	0	2	3	0	0	3
20%	0	2	0	4	0	3	0	4	0	2	3	0	0	3
15%	0	2	0	4	0	3	0	5	0	2	2	1	0	3
10%	0	2	0	4	0	3	0	5	0	2	1	2	0	3

Appendix 6

Distribution of the animals over the use of antibiotics at drying off on a low BTSCC farm with a 10% smaller infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	12		22		2		4		0		1		1	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
95%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
90%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
85%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
80%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
75%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
70%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
65%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
60%	0	12	19	2	0	2	4	0	0	0	1	0	1	0
55%	0	12	17	5	0	2	4	0	0	0	1	0	1	0
50%	0	12	15	7	0	2	4	0	0	0	1	0	1	0
45%	0	12	12	9	0	2	4	0	0	0	1	0	1	0
40%	0	12	10	12	0	2	4	0	0	0	1	0	1	0
35%	0	12	8	14	0	2	4	0	0	0	1	0	1	0
30%	0	12	6	16	0	2	4	0	0	0	1	0	1	0
25%	0	12	3	18	0	2	4	0	0	0	1	0	1	0
20%	0	12	1	21	0	2	4	0	0	0	1	0	1	0
15%	0	12	0	22	0	2	4	1	0	0	1	0	0	1
10%	0	12	0	22	0	2	1	3	0	0	1	0	0	1

Appendix 7

Summarized output of the Dutch average farm with a 10% higher infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	135.72	4.24	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
95%	128.94	4.03	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
90%	122.15	3.82	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
85%	115.37	3.61	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
80%	108.58	3.39	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
75%	101.79	3.18	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
70%	95.01	2.97	43.36	4.20	13.13%	4.16	13.00%	91.67	2.86
65%	88.22	2.76	43.59	4.26	13.31%	4.25	13.28%	88.22	2.76
60%	81.43	2.54	44.21	4.40	13.75%	4.41	13.78%	81.43	2.54
55%	74.65	2.33	45.02	4.56	14.25%	4.59	14.34%	74.65	2.33
50%	67.86	2.12	45.89	4.73	14.78%	4.78	14.94%	67.86	2.12
45%	61.08	1.91	46.88	4.90	15.31%	5.02	15.69%	61.08	1.91
40%	54.29	1.70	47.88	5.08	15.88%	5.25	16.41%	54.29	1.70
35%	47.50	1.48	48.90	5.26	16.44%	5.48	17.13%	47.50	1.48
30%	40.72	1.27	50.04	5.47	17.09%	5.64	17.63%	40.72	1.27
25%	33.93	1.06	51.18	5.68	17.75%	5.80	18.13%	33.93	1.06
20%	27.14	0.85	52.14	5.92	18.50%	5.93	18.53%	27.14	0.85
15%	20.36	0.64	53.73	6.17	19.28%	6.03	18.84%	20.36	0.64
10%	13.57	0.42	55.05	6.43	20.09%	6.12	19.13%	13.57	0.42

Summarized output of the high BTSCC farm with a 10% higher infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	89.07	4.24	€ 44.37	2.83	13.48%	2.71	12.90%	69.14	3.29
95%	84.62	4.03	€ 44.37	2.83	13.48%	2.71	12.90%	69.14	3.29
90%	80.16	3.82	€ 44.37	2.83	13.48%	2.71	12.90%	69.14	3.29
85%	75.71	3.61	€ 44.37	2.83	13.48%	2.71	12.90%	69.14	3.29
80%	71.26	3.39	€ 44.37	2.83	13.48%	2.71	12.90%	69.14	3.29
75%	66.80	3.18	€ 44.61	2.87	13.67%	2.77	13.19%	66.80	3.18
70%	62.35	2.97	€ 45.13	2.95	14.05%	2.88	13.71%	62.35	2.97
65%	57.90	2.76	€ 45.93	3.06	14.57%	2.99	14.24%	57.90	2.76
60%	53.44	2.54	€ 46.73	3.17	15.10%	3.11	14.81%	53.44	2.54
55%	48.99	2.33	€ 47.53	3.27	15.57%	3.23	15.38%	48.99	2.33
50%	44.53	2.12	€ 48.40	3.38	16.10%	3.36	16.00%	44.53	2.12
45%	40.08	1.91	€ 49.38	3.50	16.67%	3.51	16.71%	40.08	1.91
40%	35.63	1.70	€ 50.36	3.61	17.19%	3.67	17.48%	35.63	1.70
35%	31.17	1.48	€ 51.45	3.75	17.86%	3.78	18.00%	31.17	1.48
30%	26.72	1.27	€ 52.57	3.89	18.52%	3.89	18.52%	26.72	1.27
25%	22.27	1.06	€ 53.77	4.04	19.24%	3.97	18.90%	22.27	1.06
20%	17.81	0.85	€ 55.07	4.21	20.05%	4.03	19.19%	17.81	0.85
15%	13.36	0.64	€ 56.37	4.38	20.86%	4.10	19.52%	13.36	0.64
10%	8.91	0.42	€ 57.67	4.55	21.67%	4.16	19.81%	8.91	0.42

Summarized output of the low BTSCC farm with a 10% higher infection rate at drying off without antibiotics.

Percentage allowed antibiotics (%)	Maximum antibiotics used in total (dd/100 days)	Maximum antibiotics used per animal (dd/100 days)	Economic costs per animal (€)	Clinical mastitis cases (#)	Clinical mastitis chance per animal (%)	Subclinical mastitis cases (#)	Subclinical mastitis chance per animal (%)	Actually amount of antibiotics used (dd/100 days)	Actually amount of antibiotics used per animal (dd/100 days)
100%	178.14	4.24	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
95%	169.23	4.03	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
90%	160.32	3.82	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
85%	151.42	3.61	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
80%	142.51	3.39	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
75%	133.60	3.18	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
70%	124.70	2.97	40.55	5.51	13.12%	3.72	8.86%	118.35	2.82
65%	115.79	2.76	40.74	5.56	13.24%	3.79	9.02%	115.79	2.76
60%	106.88	2.54	41.54	5.77	13.74%	4.02	9.57%	106.88	2.54
55%	97.98	2.33	42.35	5.99	14.26%	4.25	10.12%	97.98	2.33
50%	89.07	2.12	43.16	6.20	14.76%	4.48	10.67%	89.07	2.12
45%	80.16	1.91	43.97	6.41	15.26%	4.71	11.21%	80.16	1.91
40%	71.26	1.70	44.77	6.63	15.79%	4.95	11.79%	71.26	1.70
35%	62.35	1.48	45.58	6.84	16.29%	5.18	12.33%	62.35	1.48
30%	53.44	1.27	46.39	7.05	16.79%	5.41	12.88%	53.44	1.27
25%	44.53	1.06	47.20	7.27	17.31%	5.64	13.43%	44.53	1.06
20%	35.63	0.85	48.00	7.48	17.81%	5.87	13.98%	35.63	0.85
15%	26.72	0.64	49.05	7.74	18.43%	6.09	14.50%	26.72	0.64
10%	17.81	0.42	50.36	8.08	19.24%	6.22	14.81%	17.81	0.42

Appendix 8

Distribution of the animals over the use of antibiotics at drying off on a Dutch average farm with a 10% higher infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	6		4		4		5		2		5		5	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
95%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
90%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
85%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
80%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
75%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
70%	0	6	4	0	0	4	5	0	2	0	5	0	5	0
65%	0	6	4	0	0	4	5	0	1	1	5	0	5	0
60%	0	6	3	1	0	4	5	0	0	2	5	0	5	0
55%	0	6	1	3	0	4	5	0	0	2	5	0	5	0
50%	0	6	0	4	0	4	5	0	0	2	5	0	5	0
45%	0	6	0	4	0	4	5	0	0	2	5	0	3	2
40%	0	6	0	4	0	4	5	0	0	2	5	0	2	4
35%	0	6	0	4	0	4	5	0	0	2	4	0	0	5
30%	0	6	0	4	0	4	5	0	0	2	3	2	0	5
25%	0	6	0	4	0	4	5	0	0	2	1	4	0	5
20%	0	6	0	4	0	4	5	1	0	2	0	5	0	5
15%	0	6	0	4	0	4	3	3	0	2	0	5	0	5
10%	0	6	0	4	0	4	1	4	0	2	0	5	0	5

Appendix 9

Distribution of the animals over the use of antibiotics at drying off on a high BTSCC farm with a 10% higher infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	2		4		3		5		2		3		3	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
95%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
90%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
85%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
80%	0	2	4	0	0	3	5	0	2	0	3	0	3	0
75%	0	2	4	0	0	3	5	0	1	1	3	0	3	0
70%	0	2	4	0	0	3	5	0	0	2	3	0	3	0
65%	0	2	3	1	0	3	5	0	0	2	3	0	3	0
60%	0	2	2	3	0	3	5	0	0	2	3	0	3	0
55%	0	2	1	4	0	3	5	0	0	2	3	0	3	0
50%	0	2	0	4	0	3	5	0	0	2	3	0	3	0
45%	0	2	0	4	0	3	5	0	0	2	3	0	1	2
40%	0	2	0	4	0	3	5	0	0	2	3	0	0	3
35%	0	2	0	4	0	3	5	0	0	2	2	1	0	3
30%	0	2	0	4	0	3	5	0	0	2	1	2	0	3
25%	0	2	0	4	0	3	4	1	0	2	0	3	0	3
20%	0	2	0	4	0	3	3	2	0	2	0	3	0	3
15%	0	2	0	4	0	3	2	3	0	2	0	3	0	3
10%	0	2	0	4	0	3	1	4	0	2	0	3	0	3

Appendix 10

Distribution of the animals over the use of antibiotics at drying off on a low BTSCC farm with a 10% higher infection rate at drying off without antibiotics.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
Parity	Heifer		Cow		Heifer		Cow		Heifer		Cow		Cow	
SCC (*1000 cells/mL)	0-50		0-50		50-100		50-100		100-150		100-150		150-250	
Number of animals	12		22		2		4		0		1		1	
Antibiotic use	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Activity number (Xi)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage allowed antibiotics (%)														
100%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
95%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
90%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
85%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
80%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
75%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
70%	0	12	22	0	0	2	4	0	0	0	1	0	1	0
65%	0	12	21	0	0	2	4	0	0	0	1	0	1	0
60%	0	12	19	3	0	2	4	0	0	0	1	0	1	0
55%	0	12	17	5	0	2	4	0	0	0	1	0	1	0
50%	0	12	14	7	0	2	4	0	0	0	1	0	1	0
45%	0	12	12	10	0	2	4	0	0	0	1	0	1	0
40%	0	12	10	12	0	2	4	0	0	0	1	0	1	0
35%	0	12	8	14	0	2	4	0	0	0	1	0	1	0
30%	0	12	5	17	0	2	4	0	0	0	1	0	1	0
25%	0	12	3	19	0	2	4	0	0	0	1	0	1	0
20%	0	12	1	21	0	2	4	0	0	0	1	0	1	0
15%	0	12	0	22	0	2	4	1	0	0	0	1	0	1
10%	0	12	0	22	0	2	1	3	0	0	0	1	0	1