Use of partial budget models to determine the economic impact of mastitis in dairy goats and the economic benefits of lactational treatment of subclinical mastitis

Abstract

Three partial budget models were developed to explore the costs of mastitis in dairy goats. The models were calculated at goat level and farm level. Input variables were deterministic data based on the literature, experts and dairy goat prices, all in Dutch circumstances. Sensitivity analyses were performed for the partial budget models to identify input parameters with strong impact on the net results.

With the first model are the total costs of mastitis on an average dairy goat farm of 700 goats in Dutch circumstances calculated. The total costs at farm level were about €3500/year and at goat level about €5/ year. In spite of the low costs per goat, are the total costs of mastitis for an average dairy goat farm 69 percent of the costs of mastitis on an average dairy cow farm of 65 cows. Clinical mastitis is very expensive for dairy goat farmers in comparison of subclinical mastitis. The costs of clinical mastitis for a dairy goat farm of 700 goats exceed the costs of subclinical mastitis in case of nine clinical mastitis cases per year. Subclinical mastitis is accountable for 63% of the total economic losses of mastitis. Production loss is responsible for 33% of the economic losses of clinical mastitis, 100% of subclinical mastitis and 75% of the total economic losses of mastitis. Culling costs are accountable for 66% of the costs in clinical mastitis and 24% of the total costs of mastitis. Treatment and labour have a small influence on the total economic losses of mastitis at farm level (2%).

With the second model are the direct and indirect costs of a goat with subclinical mastitis at goat level calculated for one year. The costs of goat with a subclinical mastitis are about €65/goat/year. Production loss is accountable for 68%, contagious transmission for 17% and the increased chance of clinical flare-up for 15% of the total costs of subclinical mastitis goat/year. Prominent parameters in this partial budget model were the degree of production loss, the reproduction ratio and the chance of clinical flare-up.

With the last model we had calculated the benefits of diagnosing and treating subclinical mastitis during lactation. We can't advise diagnosing and treating subclinical mastitis during lactation; the benefits are about -€ 5.900 per year for 700 goats. The profits of curing doesn't compensate for the high costs of diagnosing and treating. The costs of withdrawal of milk are paradoxical more than the revenues of the increase milk production after treatment. The reasons are the relatively bad test characteristics of diagnosing in comparison with the relatively low prevalence of subclinical mastitis.

Introduction

Subclincal mastitis in dairy goats is a common problem for farmers. Contreras et al. (2003) clearly shows that the prevalence of subclinical mastitis has been a great variation in different studies. The prevalence of goats with a subclinical infection is between the 19.4% and the 47% and the prevalence of halves with a subclinical intramammary infection (IMI) in goats is between the 6.5% and the 67%. Bergonier et al. (2003) assessed that 22 percent of all subclinical IMI's on dairy goat farms are major infections.

Koop et al. (2009) found a prevalence of 41 percent for subclinical mastitis under Dutch circumstances and a prevalence of 2,35 percent for major infections. Major infectors are those pathogens that cause a subclinical IMI with milk production loss. Those pathogens, bacteria, found by Koop et al. (2009), are Staphylococcus aureus, Arcanobacterium pyogenes, esculin positive cocci, Streptococcus dysgalactiae and gram negative bacteria.

Leitner et al. (2004a), Leitner et al. (2004b), Merlin et al. (2004) and Leitner et al. (2007) describes that milk yields of glands with a subclinical infection were significant lower than the milk yields of uninfected glands. However the concentration of fat does not differ between health glands and does with a subclinical infection.

The total protein in milk is significant higher in infected halves than in uninfected ones. Leitner et al. (2004a) found that the whey protein and albumin concentrations were higher by a subclinical infection, but that the casein concentration in the milk does, also like fat, not differ between health and infected glands. Towards drying off, protein concentration increase significantly in milk from uninfected glands, but not in that from infected ones (Leitner et al. (2007).

Min et al. (2007) studied the effects of subclinical mastitis on milk somatic cell count and the milk composition in udder halves of dairy goats. They conclude that the daily average milk production, the protein and the fat concentration did not significantly differ between infected and uninfected goats.

The major income for dairy goat farmers exists of the milk revenues of there goats. In the Netherlands, dairy goat farmers get there milk revenues paid out in kilogram fat and protein. Because subclinical mastitis doesn't influence the milk qualitatively, only the decreased milk production causes direct economic damage. It has been confessed commonly that mastitis is an expensive problem for dairy cow farmers; the average economic losses of mastitis in cows in the Netherlands are €78/cow/ year (Hogeveen et al., 2010).

Nevertheless the costs of mastitis in dairy goat farming are still unknown. The cost of subclinical mastitis in dairy goats was only once calculated in Spain (Sánchez et al., 1997). If the costs of mastitis are made transparently, it support decision making in dairy goat farming and management measures can be taken, like in dairy cow farming.

The economic benefit of antibiotic treatment of subclinical mastitis in dairy cows caused by S. aureus is dependent on local economic conditions and on host, pathogen and management factors. On farms where transmission of S. aureus infection to other cows is likely, antibiotic treatment of cows with subclinical S. aureus mastitis is often profitable. On farms were contagious transmission of S. aureus is unlikely, extended treatment is nearly always uneconomically, but three days antibiotic treatment can be economically profitable, especially for young animals with recent infections (Swinkels et al.,2005a). Moroni et al. (2005) had monitored a herd of 88 Alpine goats in Northern Italy for a complete lactation focussing on IMI's caused by S. aureus. They concluded that there was no significant difference in milk yield or percentage of fat and protein between healthy and infected goats with S. aureus.

Based on these results, they cannot justify treatment of chronically subclinical IMI by S. aureus during lactation, at least for the prevention of lost production.

If we assume that subclinical mastitis, however, cause production losses, according to Leitner et al. (2004a), Leitner et al. (2004b), Merlin et al. (2004) and Leitner et al. (2007), is it economically justified to treat subclinical mastitis during lactation? An overview of the cost of mastitis in the Netherlands and a model that calculated the benefits of lactational treatment support decision making in dairy goat farming.

The purpose of this paper is to explore the economic impact of IMI's in dairy goat farms, the impact of subclinical IMI for one goat and the economic benefit of diagnostic and antibiotic treatment of subclinical IMI's in lactation, all in Dutch circumstances.

Method

The present study contains three partial budget models made in Microsoft Excel 2003. Partial budgeting is a relatively simple method to calculate the economic effect on small changes in a complex system. Partial budgeting was used to develop deterministic models that explored; the economic impact of mastitis in dairy goat farms, the impact of subclinical mastitis for one goat and the economic benefit of diagnosing and treating subclinical mastitis during lactation in Dutch circumstances.
In a partial budget model, economic effects are calculated as the sum of positive economic effects minus the negative economic effect. Positive economic effects are calculated as extra revenues plus reduced costs. The negative economic effects are calculated as the reduced revenues plus the extra costs. With the first model, the impact of mastitis in a dairy goat farm, is calculated at farm level during one year. With the second model, the economic impact of subclinical mastitis for a goat, is calculated at goat level with a lactation of 365 days. With the last partial budget model, the economic benefits of diagnosing and treating of subclinical mastitis during lactation, are the positive and negative economic effects calculated at farm level during a lactation of one year.
Input variables were deterministic data based on the literature, experts and dairy goat prices all under Dutch circumstances.
Sensitivity analyses were performed for the three models to identify input parameters with strong impact on the net results.

Model 1. The economic impact of mastitis on a dairy goat farm

The first partial budget model is developed to explore the economic impact of IMI on a dairy goat farm. Costs and benefits were calculated at farm level during one year.

This model is specifically adapted for major infections, because minor infections doesn't result in reduction of milk production (unpublished data of Koop., G). We assume that the change that minor infection results in clinical mastitis is negligible.

Subclinical mastitis. Subclinical mastitis is accompanied with the loss of milk production [1].

[1] = $N \cdot Prev \cdot MP_{YEAR} \cdot MP_{SUB} \cdot C_{MILK}$

Clinical mastitis. In this model, we assumed that the clinical mastitis is always treated [2]. The applied antibiotic in the calculation is penethamate hydriodid, based on the formulary of dairy goats in the Netherlands and Moroni et al. (2005). This antibiotic is either suitably for clinical as subclinical mastitis. The use of antibiotics goes companied with the costs of the withdrawal of milk (labour [4] and milk production loss [8]).

Thought if the clinical mastitis goat is treated, the goat will not always be saved and if cured, it leads in most cases to irreversible loss of function and degeneration of the infected gland [7]. We are assuming that if a goat doesn't cure after treatment, they will be removed on the farm. Consequently, either the animal is culled or the infected gland has a loss of function for the rest of the goat's lactation. Thus, clinical mastitis causes direct economic loss to the farmer (Leitner et al. 2008).

For the estimation of the culling costs [3], we assume that every stock breeder euthanasize his ill goat by a vet, unfortunately, not every goat farmer doesn't, but of animal well-being it has been, however, recommend. The destruction of carrions is legally obliges, regulation EC 1774/2002, and the Dutch government joins in paying the destruction. The replacement costs of a goat are the breeding costs. The breeding costs consist of feed intake, energy, like water, electricity, gas and diesel, veterinary service/ medication, manure remove, interest, labour, housing and falling out.

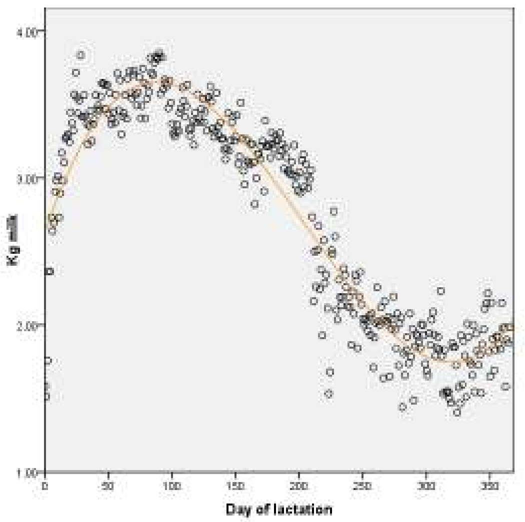
[2] = Costs of treatment = $N_{CLIN} \cdot (C_{ANTIBIOTIC} + (D_{TREATMENT} \cdot TT_{CLIN} \cdot C_{LABOUR}))$

[3] = Culling costs = $N_{CLIN} \cdot CR_{TRE.CLIN} \cdot (C_{BREEDING} + C_{DESTRUCTION} + C_{VET})$

[4] = Labour costs of the withdrawal of milk = $N_{CLIN} \cdot D_{WITHDRAWAL} \cdot T_{WITHDRAWAL} \cdot C_{LABOUR}$

For the estimation of the reduced revenues of milk production loss, caused by the withdrawal of milk and decreased milk production after treatment and cure of clinical mastitis, we had used data of Koop et al. (2009). A lactation curve (graph 1) and a formula [5] of the lactation curve from data of Koop et al. (2009), was made by SPSS 16.0.2 for windows.

Graph 1. Lactation curve of a goat, originating from data of Koop et al. (2009), (R=0.905).



[5] = $MP(X) = 2.63 + 0.026X - 0.000187X^2 + 3.06 \cdot 10^{-7} X^3$

The next formula [6] was used to estimate the total milk production in kg from day X to the end of the lactation (day 365).

[6] = $MP_{365-}(X) = 1000 - (2.63X + 0.013X^2 - 0.00006X^3 + 7.65 \cdot 10^{-8} X^4)$

[7] = $N_{CLIN} \cdot CR_{CLIN} \cdot C_{MILK} \cdot MP_{365-}(D_{CLIN}) \cdot MP_{TRE.CLIN}$

[8] = $N_{CLIN} \cdot C_{MILK} \cdot D_{WITHDRAWAL} \cdot MP(D_{CLIN})$

Experts estimate the effect of reduced milk production on the feed intake negligible; because goats don't eat what they need, but eat what they get. If less energy is going to the milk than the goat will store more fat.

Model 2. The economic impact of subclinical mastitis on one goat

The positive and negative economic effects for this model are calculated at goat level during a lactation of 365 days.

A goat with a subclinical mastitis has more chance to get a clinical mastitis than other goats. The increase chance of getting clinical mastitis is an extra cost and will be taken in calculation. The chance of clinical flare-up is expected low, because the prevalence of subclinical mastitis is relatively high in comparison with the numbers of clinical mastitis in a year. In the deterministic calculation, this chance is set on 0.03.

The calculation of the estimated average cost of clinical mastitis used in this model is based on decisions and chances. The farmer can make the decision to treat or not to treat a goat with a clinical mastitis. And the chance that a goat cured is dependent on the choice that the farmer had made. There are four ways. The farmer treats the goat and the goat is cured [9], or the goat will die [10]. The farmer doesn't treat the goat and the goat cured by her one [11], or the goat will die [12]. The treatment decision for a goat with clinical mastitis is ten percent. This percentage seems to be low, but experts think this is reasonable because it's very difficult to see the symptoms of clinical mastitis. Especially, most farmers don't fore milking (in comparison with dairy cow farmers), and don't see the clots in the milk. Moreover goats don't show much signs of illness.

[9] = $C_{ANTIBIOTIC} + (D_{TREATMENT} \cdot TT_{CLIN} \cdot C_{LABOUR}) + (D_{WITHDRAWAL} \cdot T_{WITHDRAWAL} \cdot C_{LABOUR}) + (MP(D_{CLIN}) \cdot MP_{CLIN} \cdot D_{WITHDRAWAL} \cdot C_{MILK}) + (MP_{365-}(D_{CLIN}) \cdot MP_{TRE.CLIN} \cdot C_{MILK})$

[10] = $C_{ANTIBIOTIC} + (D_{TREATMENT} \cdot TT_{CLIN} \cdot C_{LABOUR}) + (D_{WITHDRAWAL} \cdot T_{WITHDRAWAL} \cdot C_{LABOUR}) + (MP(D_{CLIN}) \cdot MP_{CLIN} \cdot D_{WITHDRAWAL} \cdot C_{MILK}) + C_{BREEDING} + C_{DESTRUCTION} + C_{VET}$

[11] = $C_{BREEDING} + C_{DESTRUCTION} + C_{VET}$

[12] = $(MP_{365-}(D_{CLIN}) \cdot MP_{TRE.CLIN} \cdot C_{MILK})$

The mean cost of clinical mastitis is calculated with the next formula [13].

[13] = $(T_{CLIN} \cdot CR_{TRE.CLIN} \cdot [9]) + (T_{CLIN} \cdot (1-CR_{TRE.CLIN}) \cdot [10]) + ((1- T_{CLIN}) \cdot (1-CR_{CLIN}) \cdot [11]) + ((1- T_{CLIN}) \cdot CR_{CLIN} \cdot [12]$

The cost of the increased chance of getting a clinical mastitis is [14].

[14] = $Pro_{CLIN} \cdot [13]$

The reduced revenue of the decreased milk production, caused by subclinical mastitis, is calculated with the next formula [15].

[15] = $MP_{365-}(D_{SUB}) \cdot MP_{SUB} \cdot C_{MILK}$

The prevalence of IMI's increase at the age of goats. Increasing prevalence of age may be due to the increased length of exposure to pathogens in older compared to younger animals. Additionally, where the duration of infection is long and the spontaneous cure rate low, prevalence will increase (McDougall et al., 2002). Goats with a subclinical mastitis and continued bacterial shedding cause extended exposure of the whole herd to pathogenic bacteria which may result in infection of other goats in a herd.

The reproduction ratio (R) is defined as the total number of new infections caused by an infected goat during its duration of infection. The R is a quotient of the infectiousness of a pathogen (β) and the recovery parameter (α). The β is defined as the number of new infections in a certain time and is the product of the total contacts between animals (y) and the fraction of the contact that leads to new infections (p). The duration of the infectious period is abbreviated as the T and the infectiousness of an infected goat will stop with the speed 1/T which is defined as α.

The duration of infection is different of various pathogens (Contreras et al., 1997), (Moroni et al., 2005). And the extension to which transmission to other goats occur is species dependent and unfortunately, little information is available about the transmission rate of pathogens responsible of IMI's in goats. S. aureus has a little prevalence and little capacity for transmission among goats. The herds in which it is present usually have only few infected animals. S. aureus caprine strains are less contagious than bovine ones (Contreras et al., 2003). Also the prevalence of other major pathogens is low. In our model, in consideration that the R is lower in comparison than cows, is the R set on 0.20.

The cost of contagious transmission is calculated in the next formula [16].

$$[16] = ([14] + [15]) \cdot R$$

The reduced costs of the decline in feed intake is also now estimated on zero for the same reason as the first partial budget model.

Model 3. The economic benefits of diagnosing and treating of subclinical mastitis during lactation

For the diagnosis of subclinical mastitis during lactation we had used in this model the determination of the somatic cell count (SCC). The determination of the SSC for subclinical mastitis has a sensitivity and specificity of respectively 0.9 and 0.9 for the detection of Staphylococcus aureus (unpublished data of Koop, G.).

A lot of goat farmers are using the periodic milk control for the genetic improvement of there herd. It is easy to measure the SCC extra during the this periodic milk control. The extra costs of diagnostic for a dairy goat farmer who is using the milk control for there operational management is obviously those of determination of milk samples on SCC [17]. The costs for farmers who don't use the milk control for there management are much higher [18], because of the extra cost of purchasing, subscription and labour.

$$[17] = N \cdot C_{DETERMINATION}$$

$$[18] = (N \cdot C_{DETERMINATION}) + C_{SUBSCRIPTION} + (T_{CONTROL} \cdot C_{LABOUR})$$

The goats that are selected by the SCC will be treated. We had to keep in mind that those goats selected [19] are the true positives and the false positives. Treating the goats during lactation brings out the costs of antibiotic [20], milk production loss [21] because of the withdrawal of milk and the cost of labour

[22], because of the administering of antibiotics to the selected goats and the withdrawal of milk.

$[19] = (N \cdot Prev \cdot Se) + (N \cdot Prev \cdot (1\text{-}Sp))$

$[20] = [19] \cdot C_{ANTIBIOTIC}$

$[21] = [19] \cdot MP(DT_{SUB}) \cdot MP_{SUB} \cdot D_{WITHDRAWAL} \cdot C_{MILK}$

$[22] = [19] \cdot C_{LABOUR} \cdot ((D_{WITHDRAWAL} \cdot T_{WITHDRAWAL}) + (D_{TREATMENT} \cdot TT_{SUB}))$

The benefits of treatment of subclinical mastitis are the reduction of the probability of clinical flare-ups [23], reduction of contagious transmission to other goats [24] and the increase milk production after treatment.

$[23] = (N \cdot Prev \cdot Se) \cdot CR_{TRE.SUB} \cdot [13]$

$[24] = (N \cdot Prev \cdot Se) \cdot CR_{TRE.SUB} \cdot [16]$

There are different views about the effect of treatment and cure of subclinical mastitis on the milk production. St. Rose et al. (2003) concluded in her study of parenteral administer of penethamate hydriodide in dairy cows that there was no significant effect of treatment on the milk production. Sandgren et al. (2008) also concluded that the treatment of cows had no significant effect on the daily milk yield. The study of Karzis et al. (2007) concluded also that treatment with an antibiotic did not affect the milk yield of the goats. The lack of effect of treatment on milk production may indicate that damage caused by subclinical infection is persistent. Anyhow some experts think that the milk production should increase after cure of subclinical mastitis. We are assuming that treatment of subclinical mastitis during lactation will increase the milk production until the five percent milk production loss of a standard lactation. The extra revenue of the increase milk production after cure is calculated with the next formula [25]

$[25] = MP_{365\text{-}}(DT_{SUB} - D_{WITHDRAWAL}) \cdot (MP_{SUB} - MP_{TRE.SUB}) \cdot (N \cdot Prev \cdot Se) \cdot C_{MILK}$

Sensitivity analysis

Sensitivity analyses are used to calculate what happens to the net result if one input variable at a time is changed from the average situation. Values for input variables in the sensitivity analyses were based on information in the literature. When there was no information in the literature, expertise of experts or the author was used.

When input variables have a strong impact on the economic outcome, further research for this value of parameter may be indicated. The performed variables and the results of the sensitivity analyses are shown in table 3, 5 and 7.

Results

Model 1. The economic impact of mastitis on a dairy goat farm

The result of the calculation of the economic impact of mastitis on a dairy goat farm is shown in table 2. The total costs of mastitis on a dairy goat farm of 700 goats is € 3484/year, that is €4,98/goat/year. Subclinical mastitis is responsible for 63% of the total costs of IMI on an average dairy goat farm, although the prevalence of subclinical mastitis is a lot of times more than clinical mastitis. Production losses accounted for 33% of the economic losses of clinical mastitis, 100% for subclinical mastitis and 75% of the total economic losses caused by IMI's. Culling costs is an other factor accounting for a large part of the economic losses, 66% for clinical mastitis and 24% of the total costs of IMI's. Treatment and labour have only a small influence on the total economic losses (2%).

Table 2. Partial budget model of the deterministic calculation of the impact of mastitis on a dairy goat farm.

Contribution to economic effect	Net profit
Subclinical mastitis	
Reduced revenu	
Decline in milk production	-€ 2.207,13
Reduced costs	
Redueced feed intake	€ 0,00
Clinical mastitis	
Extra costs	
Early remove of goats/ culling	-€ 839,00
Treatment	-€ 52,50
Labor for withdrawal milk	-€ 30,00
Reduced revenue	
Decline in milk production after cure of clinical mastitis	-€ 385,80
Production loss, because of withdrawal milk	-€ 34,01
Reduced costs	
Redueced feed intake	€ 0,00
Total costs of mastitis for a dairy goat farm	-€ 3.484,43
Total costs of mastitis for one goat	-€ 4,98

The result of the sensitivity analysis for the partial budget model, the economic impact of mastitis on an average dairy goat farm, is shown in table 3. The amount of clinical mastitis cases on a dairy goat farm has a very strong impact on the economic net result. The prevalence of major infections and the degree of production loss caused by subclinical mastitis have also a large influence on the economic result.

The impact of which day a subclinical mastitis became clinical and the labour costs are negligible for the calculation. The milk price and the degree of recovery of milk production after treatment of clinical mastitis have only a small influence on the net result.

Table 3. Sensitivity analysis: Effect on the net profit of input variables. Each time one input variable is changed, the others remain the same.

Variable	Value	**Net effect** Farm	Per goat
Deterministic calculation		-€ 3.484,44	-€ 4,98
Prevalence of major infection in the population (%).	6		
	2.4	-€ 2.160,16	-€ 3,09
	10.3	-€ 5.066,21	-€ 7,24
Milk production loss one halve subclinical mastitis (% decrease).	11,01		
	0	-€ 1.277,30	-€ 1,82
	20	-€ 5.286,62	-€ 7,55
	40	-€ 9.295,94	-€ 13,28
Clinical flare-up of subclinical mastitis (days post partum).	60		
	30	-€ 3.533,46	-€ 5,05
	70	-€ 3.467,29	-€ 4,95
Clinical mastitis infections per year (n).	5		
	10	-€ 4.761,74	-€ 6,80
	15	-€ 6.039,04	-€ 8,63
	20	-€ 7.316,35	-€ 10,45
	25	-€ 8.593,65	-€ 12,28
Recovery of production after treatment and cure of clinical mastitis (% decrease).	40		
	20	-€ 3.291,53	-€ 4,70
	100	-€ 4.063,14	-€ 5,80
Milk price (€/100 kg).	47,73		
	43	-€ 3.227,48	-€ 4,61
	52	-€ 3.716,40	-€ 5,31
Labour (€/h).	18		
	0	€ 3.469,44	-€ 4,96

Model 2. The economic impact of subclinical mastitis on one goat

The economic loss caused by subclinical mastitis is calculated for one goat on €76 per year, shown in table 4. The production losses accounted for 68% of the economic losses of subclinical mastitis. Transmissions of pathogens to other goats are responsible for 17% of the economic losses and the contribution of increased chance of clinical flare-up 15 % on the net result.

Table 4. Partial budget model of the deterministic calculation of the economic impact of subclinical mastitis on one goat.

Contribution to economic effect	Net profit
Extra costs	
Contagious transmission of other goats	-€ 10,84
Increase chance of clinical mastitis	-€ 9,87
Reduced revenue	
Decline in milk production	-€ 44,32
Reduced costs	
Reduced feed intake	€ 0,00
Total cost of subclinical mastitis for a goat	-€ 65,02

The result of the sensitivity analysis, the impact of subclinical mastitis on a goat, is shown in table 5. The reproductive ratio, the milk production loss and the probability of clinical flare-up are influential variables on the net result. The day on which the goat gets a subclinical mastitis is not depending on a couple of days, but a large difference in days, instance day zero or hundred, is however, noticeable on the net profit. Labour costs, the chance that a clinical mastitis will be treated and the possible recovery of production after treatment and cure of clinical mastitis are negligible costs for a goat with a subclinical mastitis. Also the day of clinical flare-up doesn't influence the outcome of the calculation very much.

Table 5. Sensitivity analysis: Effect on the net profit of input variables. Each time one input variable is changed.

Variable	Value	Net effect
Deterministic calculation		€ 65,02
Reproductive ratio	0,2	
	0,4	-€ 75,86
	1	-€ 108,37
Milk production loss one halve subclinical mastitis (% decrease).	11,01	
	0	-€ 11,84
	20	-€ 108,47
	40	-€ 205,10
Subclinical mastitis infection (days post partum).	50	
	0	-€ 74,87
	20	-€ 71,26
	60	-€ 62,80
	100	-€ 53,57
Clinical flare-up of subclinical mastitis (days post partum).	60	
(In the circumstance that the subclinical IMI was started on day zero).	30	-€ 74,91
	80	-€ 65,00
Clinical flare-up of subclinical mastitis (probability).	0,03	
	0,05	-€ 72,91
	0,07	-€ 80,81
	0,10	-€ 92,64
Recovery of production after treatment and cure of clinical mastitis (% decrease).	40	
	20	-€ 64,88
	100	-€ 65,44
Chance that a goat will be treated for clinical mastitis.	0,1	
	0	-€ 65,26
	1	-€ 62,84
Milk price (€/ 100kg).	47,73	
	43	-€ 59,72
	52	-€ 69,80
Labour (€/ h).	18	
	0	-€ 64,99

Model 3. The economic benefit of diagnostic and treatment of subclinical mastitis during lactation

The average economic benefit of diagnosing and treating subclinical mastitis during lactation on an average farm of 700 dairy goats is -€ 5.931,73 per year. The high cost of diagnosing (€4480) doesn't compensate for the profits of curing, even when the farmer had only paid for the treatment and taken the loss of the withdrawal of milk. The cost of withdrawal of milk is paradoxical more than the revenues of the increased milk production after treatment.

Table 6. Partial budget model of the profitability of diagnosing and treating subclinical mastitis during lactation.

Contribution to economic effect	Net profit
Extra costs	
Treatment	-€ 770,00
Labor	-€ 932,40
Diagnostics of subclinical mastitis	-€ 4.480,00
Reduced revenue	
Milk discard because of antibiotic residue	-€ 642,27
Reduced costs	
Reduction in probability of clinical mastitis	€ 220,03
Reduction of contagious transmission	€ 241,68
Extra revenue	
Increase in milk production after cure	€ 438,23
Net profit	-€ 5.931,73

All individual changes of input variables in the sensitivity analysis don't result in a positive net profit, shown in table 7. If all input variables are changed together, all in a direction of strong positive influence on economic profit, treatment may be advantageous. This scenario is only not reasonable. Nevertheless the costs of labour, taking part in the milk control or not and the milk production loss caused by subclinical mastitis are variables with a strong contribution on the net result. The decrease of milk production at the end of lactation and with that the decrease of milk discarding, makes the treatment of subclinical mastitis at the end of lactation a little bit cheaper. Although this ranges is marginal on the net profit.

Table 7. Sensitivity analysis: Effect of input variables on the net profit. Each time one input variable is changed, the other variables remain the same.

Variable	Value	Net effect
Deterministic calculation		-€ 5.932,73
Reproductive ratio	0,2	
	0,4	-€ 5.690,05
	1	-€ 4.965,02
Prevalence of major infection in the population (%).	6	
	2.4	-€ 6.014,07
	10.3	-€ 5.866,38
Milk production loss one halve subclinical mastitis (% decrease).	11,01	
(In the circumstance that there is no increase in milk production after treatment).	0	-€ 6.449,42
(In the circumstance that there is no increase in milk production after treatment).	20	-€ 5.211,32
(In the circumstance that there is no increase in milk production after treatment).	40	-€ 3.608,63
Milk production after treatment of subclinical mastitis (% decrease standard lactation).	5	
	0	-€ 5.567,14
	11,01	-€ 6.369,96
Treatment of subclinical mastitis (days post partum).	90	
	20	-€ 5.673,27
	60	-€ 5.846,89
	160	-€ 6.008,83
	200	-€ 6.001,44
Probability of clinical flare-up of subclinical mastitis during lactation.	0,03	
	0	-€ 6.151,76
	0,1	-€ 5.418,32
Cure rate of the treatment of subclinical mastitis.	0,59	
	0.2	-€ 6.526,61
	1	-€ 5.306,35
Milk price (€/ 100kg).	47,73	
	43	-€ 5.911,51
	52	-€ 5.949,98
Antibiotic price (€).	7,5	
	5	-€ 5.672,73
	10	-€ 6.190,73
	12,5	-€ 6.449,73
	15	-€ 6.708,73
Labour (€/h).	18	
	0	-€ 4.999,33
Farmers who only use the milk control for the diagnostics of subclinical IMI.		-€ 7.495,73

Discussion

Partial budgeting is a relatively simple method to assess the economic impact of mastitis and the economic benefits of diagnosing and treating of subclinical mastitis during lactation. However, as for any simple model, assumptions are relatively crude when compared with the complexity of reality. And because of the lack of information a lot of parameters were estimated. To address simplifications and assumptions like the ones used in our model and sensitivity analysis, and to obtain more accurate estimates of the range of economic effects and the probability of specific outcomes within that range, a stochastic model aimed on the distinction between pathogens would be need to developed. Also studies to several parameters would be needed to optimize the usefulness of the model

Mastitis is a common problem in dairy goat farms; its incurred loss for an average farm of 700 goats is € 3484 per year. For the greater part (63%) are the subclinical infections accountable for this damage. This conclusion corresponds with that of Huijps et al. (2008) accomplished with dairy cows in the Netherlands, where subclinical mastitis is responsible for 55% of the total losses of mastitis. Also in her study were the only costs of subclinical mastitis the milk production losses. Nevertheless the total costs of clinical mastitis in dairy cow farms approach that of subclinical mastitis. The high prevalence of clinical mastitis in dairy cows in comparison with dairy goats are the reason for this difference. Despite the prevalence of clinical mastitis in dairy goats are low, does they have paradigmatic a strong impact on the economic result. For an average dairy goat farm of 700 goats, the costs of clinical mastitis exceed that of subclinical mastitis in case of nine clinical mastitis cases per year.

The average costs of mastitis for dairy cows are 78 €/cow/year (Hogeveen et al., 2010) in comparison of dairy goats 5 €/goat/year. Nevertheless a dairy goat farm has more animals, and as a result, the total costs of mastitis in dairy goats approach that of dairy cows. On an average dairy cow farm of 65 cows are the total costs of mastitis € 5070 in comparison of € 3484 in dairy goats. In spite of more animals in dairy goat farms are the total economic losses of mastitis lower than dairy cow farms. The total costs of mastitis in dairy goat farms are average 69 percent of the costs of mastitis in dairy cow farms of 65 cows. The decrease of milk production loss caused by subclinical mastitis has a strong influence on the net result, and because the quality is a very uncertain factor, further research for this parameter would be necessary to make a more realistic estimation of the reality.

It’s not economically justified to diagnose en treat subclinical mastitis during lactation in dairy goats. There are many partial budget models made to determine the economic benefits of antibiotic treatment of subclinical mastitis during lactation in dairy cows. Also for the average cow treatment had not been economically justified (Swinkels et al., 2005a), (Swinkels et al., 2005b) and (Steeneveld et al., 2007). However, for animals with a high risk of contagious transmission of *S. aureus* to other cows in the herd is antibiotic treatment of subclinical mastitis profitable (Swinkels et al., 2005a). Moroni et al. (2005a) concluded in his study to Staphylococcus aureus isolated from chronically infected dairy goats that treatment during lactation is not justified. As a reason for this he wrote that there was no significant different of milk yields or percentages of fat and protein between healthy and infected udder halves in goats. It would be better to use the dry treatment strategy to minimize the amount of milk that would be discarded because of antibiotic residues and to decrease the risk of antibiotic resistance from overuse of antimicrobial agents.

The high negative economic side effect of diagnosing and treating subclinical mastitis during lactation in dairy goat farming is caused by the relatively bad test characteristics. The relatively low prevalence of subclinical mastitis in dairy goats is causing a high amount of false positives during testing. The current diagnostic test, specificity of 0.9 and a prevalence of 6 percent subclinical mastitis infections in a dairy goat farm of 700 animals results in 38 true positives versus 66 false positives. The positive effect of treating 38 true positives can't compensate for the extra made costs of treating unnecessary 66 goats.

In the present study are the breeding costs the invested capital at the moment of birth until the goat will be milked for the first time. Older goats produce more milk than younger goats, but older goats has more chance to be sick and as consequence of that to be culled. Also younger goats are probably genetic better than older goats. Unfortunately, all these variables are difficult to express in money and therefore not counted in the calculation.

Graph 1 was modulated for a lactation length of 365 days, while normally goats have a dry off period of a couple of weeks each year. The data was derived from the quantity of bulk milk and the number of goats in lactation at that moment. The increase milk production at the end of lactation is caused by goats that started with a new lactation. Perhaps it's was better to modulate the data to a lactation curve of 305 days. It is concluded that genotype, age and season affect the characteristics of lactation curve in goats (Montaldo et al., 1997). It's better to correct this data for all these varieties. The plotted graph is a cubic function. Other studies often modelled this kind of data using the model proposed by Wood. (Montaldo et al., 1997). A number of other possible models for modelling lactation curves specifically in dairy goats have been considered by others like; Groenewald et al. (2003) and Gipson et al. (1990).

It's interesting to compare the present study in the future with a study of the economic benefits of standard antibiotic dry off therapy. In case of standard dry off therapy, the reduced revenues would be zero, because dry off goats are not milking. Diagnostics wouldn't necessary anymore, because all goats will be standard treated. Treatment cost should grow, because more goats will be treated. Bergonier et al. (2003) concluded that 20 to 60% of subclinical infected halves in goats spontaneously cure during the dry off period and that 50 to 92,5% cure after antibiotic treatment during the dry off period.

Maroni et al (2005a) clearly show that there is resistant to some kind of antibiotics, as well as against bezylpenicillin to S. aureus, the antibiotic used in this paper. When antibiotic treatment of subclinical mastitis during lactation is recommend for dairy goat farmers, the use of antibiotics will be increase and with that the growth of antibiotic resistance against pathogens responsible for mastitis. This can be a problem for the future. Several papers report that it is possible to improve udder health in dairy goats by management measures, without the use of antibiotics. Further research in realizably and economically justify methods to prevent mastitis in dairy goats would be interesting and to compare it with the economical benefits of lactational treatment.

Conclusion

The total cost of IMI’s on a dairy goat farm of 700 goats is € 3484 per year, the average cost per goat are €4,98 per year. In spite of the low costs per goat, are the total costs of mastitis for an average dairy goat farm 69 percent of the costs of mastitis on an average dairy cow farm of 65 cows. The costs of clinical mastitis for a dairy goat farm of 700 goats exceed the costs of subclinical mastitis in case of nine clinical mastitis cases per year. Clinical mastitis is very expensive for dairy goat farmers in comparison of subclinical mastitis.

The costs of goat with a subclinical mastitis are about €65/goat/year. Prominent parameters for this model were the degree of production loss, the reproduction ratio and the chance of clinical flare-up.

We can’t advise diagnosing and treating subclinical mastitis during lactation; the benefits are about -€ 5.900 per year for 700 goats. The profits of curing doesn’t compensate for the high costs of diagnosing and treating. The costs of withdrawal of milk are paradoxical more than the revenues of the increase milk production after treatment. The reasons are the relatively bad test characteristics of diagnosing subclinical mastitis in comparison with the relatively low prevalence of subclinical mastitis.

Table 1. Values, reference of value and abbreviation of parameters used in the partial budget models for this paper.

Parameter	abbreviation	Default	Sensitivity analysis Low	High	Reference
General					
Population (n)	N	700			This paper
Milk production (kg/goat/365d)	MP	1000			This paper
Reproductive ratio	R	0.4			Experts
			0.2	1	This paper
Subclinical					
Prevalence of major infection in the population (%)	Prev	6			This paper
			2.4		Koop et al. (2009)
				10.3	Bergonier et al. (2003)
Milk production loss one halve subclinical mastitis (% decrease)	MP_{SUB}	11.01			Unpublished data Koop et al.
			0, 20, 40		This paper
Day of lactation subclinical mastitis infection (days)	D_{SUB}	50	0, 20, 60, 100		Experts
Milk production loss after treatment of subclinical IMI (% standard lactation)	$MP_{TRE..SUB}$	5	0		This paper
				11.01	St. Rose et al. (2003)
					Sandgren et al. (2008)
Day of treatment of subclinical mastitis	DT_{SUB}	90	20, 60, 160, 200		This paper
Clinical					
Clinical mastitis infections (n/year)	N_{CLIN}	5			Experts
Clinical flare-up (days post partum)	D_{CLIN}	60	30, 70		Experts
Milk production loss after treatment and cure of clinical IMI (% standard lactation)	$MP_{TRE.CLIN}$	40			Experts
			20, 100		This paper
Clinical flare-up (probability)	Pro_{CLIN}	0.03			Experts
			0, 0.1		This paper
Milk production loss acute clinical mastitis (% standard lactation)	MP_{CLIN}	100			Experts
Treatment					
Treatment of clinical mastitis (probability)	T_{CLIN}	0.1			Experts
			0, 1		This paper
Duration of treatment (days)	$D_{TREATMENT}$	1			Instruction antibiotic
Withdrawal period of the used antibiotic (days	$D_{WITHDRAWEL}$	4			Instruction antibiotic
Cure rate no treatment of clinical mastitis	CR_{CLIN}	0			Experts
Cure rate treatment of subclinical mastitis	$CR_{TRE.SUB}$	0.59			ST. Rose et al. (2003)
			0.2, 1		This paper
Cure rate treatment of clinical mastitis	$CR_{TRE.CLIN}$	0.5			Experts
Treatment clinical mastitis (minute/goat)	TT_{CLIN}	10			This paper

Treatment subclinical mastitis (minute/goat)	TT_{SUB}	2			This paper
Withdrawal of milk (minute/goat)	$T_{WITHDRAWAL}$	5			This paper
Diagnostics					
Sensitivity	Se	0.9			Unpublished data Koop et al.
Specificity	Sp	0.9			Unpublished data Koop et al.
Subscription (€/trimester)	$C_{SUBSCRIPTION}$	700			This paper
Determinations (€/goat)	$C_{DETERMINATION}$	0.40			This paper
Extra time for milk control (h/control)	$T_{CONTROL}$	6			Experts
Prices					
Milk (€/100 kg)	C_{MILK}	47.73			LTO Nederland
			43	52	This paper
Labour (€/h)	C_{LABOUR}	18			Experts
			0		This paper
Antibiotics (€/goat)	$C_{ANTIBIOTIC}$	7.5	5, 10, 12.5, 15		This paper
Breeding (€/goat)	$C_{BREEDING}$	285			Experts
Destruction (€/goat)	$C_{DESTRUCTION}$	10.60			This paper
Veterinary service, euthanisation (€)	C_{VET}	40			This paper
Feed (€)		0			Experts

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