Which criteria can be used to select antibiotic intramammary tubes for non-severe clinical mastitis therapy?

Franziska Nankemann[1], Anne Tellen[1], Luis Leon[2], Volker Krömker[1]*
[1]Hannover University of Applied Sciences and Arts, Faculty II, Microbiology, 30453 Hannover, Germany
[2]Zoetis Germany GmbH

** Corresponding author: Volker Krömker; E-Mail: volker.kroemker@hs-hannover.de*

Date submitted: 25/12/2025 *Date accepted: 05/06/2026* *Volume/Page(s): 1-7*

Abstract

The treatment of mastitis is one of the most frequent indications for antibiotic use in dairy cattle. Among the different manifestations of mastitis, non-severe clinical mastitis (CM) represents the majority of cases and thus accounts for a large proportion of antimicrobial consumption on dairy farms. While bacteriological cure (BC) is the primary measure of treatment success, no randomized controlled trials currently demonstrate significant differences in BC rates between the antibiotic intramammary injectors available in Germany. Consequently, the selection of an appropriate injector must be guided by other criteria. This article provides a structured, evidence-based overview of the most relevant decision criteria for the selection of antibiotic udder injectors for the treatment of non-severe CM, and presents a comparative economic analysis of all injectors with market relevance in Germany.

The criteria considered include the classification of active substances as critically important antimicrobials (according to EMA categorization), the resistance profile of mastitis pathogens, practical and operational factors (soft criteria), and economic calculations. For the economic analysis, direct costs were calculated for all 14 udder injectors listed in the Lila Liste, comprising medication costs, labor costs for application, and costs due to discarded milk during the withdrawal period.

Based on the available evidence, injectors containing non-critical active ingredients with short milk withdrawal times represent the most favorable choice under current regulatory and economic conditions. Soft criteria, such as once-daily application, are increasingly relevant on farms with external labor or automatic milking systems.

Keywords: bovine mastitis, treatment costs, intramammary therapy

Introduction

Antibiotic treatment is a fundamental therapeutic approach for combating bacterial infections in humans and animals. In dairy cattle, the treatment of mastitis is one of the most common reasons for the use of antimicrobials [1]. Based on the presence or absence of clinical symptoms, a distinction can be made between clinical mastitis (CM) and subclinical mastitis (SCM). According to current recommendations, clinical mastitis should be treated (targeted) during lactation, while subclinical mastitis should be treated whenever possible at drying off and not during lactation [2]. CM causes immediate, direct costs (diagnostic, veterinarian services, additional labor, milk discard) and also indirect long-term costs (reduction of milk production, increased risk of culling [3] and reproduction disorders [4]).

The measure of effectiveness of an antibiotic treatment is the bacteriological cure (BC). However, there are numerous cases of mastitis in which the BC rate cannot be increased by antibiotic therapy for various reasons. An important factor is the respective pathogen. There are pathogens that show a high spontaneous cure (e.g., Escherichia (E.) coli [5]), other pathogens show a low antibiotic cure or no antibiotic cure (Mycoplasma, Yeasts, Prototheca), and in some cases, no growth can be detected. In addition to the causative pathogen, the disease history of the respective animal and the current severity of the mastitis case must also be considered when deciding on treatment [6]. Since new infections can significantly worsen the cure success of cases already treated with antibiotics, the probability of new infections must also be taken into account when planning treatment [7]. Before starting antibiotic treatment, different factors should therefore be considered to treat only those animals that will benefit from it and are therefore worthy of treatment. With the help of on-farm tests, antibiotic use can be significantly reduced as part of targeted therapy by restricting the treatment to infections that benefit from antibiotic therapy [8,9]. It is even possible to carry out a simple antimicrobial resistance test within this framework [10].

If the clinical mastitis case is worth treating, there are many different options for antibiotic therapies. Considering the route of administration, a local intramammary application of antibiotic ointments in the type of an udder injector should be preferred. This form of application is even recommended by the European Medicines Agency (EMA) because, in contrast to systemic antibiotic administration, it does not have the negative side effect of impacting the intestinal bacteria, which can potentially lead to further development of resistance [11]. The available literature on the superiority of systemic or combined local and systemic antibiotic therapy over local therapy does not allow a clear evaluation [12,13]. A severe form of clinical mastitis with serious general health issues of the cow (fever, depression, downer cow) is the only reason that justifies systemic treatment administered parenterally to treat a possible bacteremia [14,15,16]. Considering that about 85% of clinical mastitis cases are of mild or moderate severity [17], systemic treatments should therefore be the exception rather than the rule. For this reason, the focus of this article is on the treatment of non-severe clinical cases of mastitis.

Various antibiotic udder injectors for the treatment of clinical mastitis are available in Germany. Even if more animals are treated with a targeted therapy concept, there are still many questions to be answered in every dairy farm regarding the choice of local antibiotic therapy.

The aim of this article is to compare the intramammary antibiotic injectors available in Germany from an evidence-based, pragmatic, and economic point of view. To this end, the various factors that are important for decision-making were described. In particular, the total costs for a treatment with an antibiotic udder injector with market relevance in Germany were calculated. Differences in costs among clinical history, parities, days in milk, and recurrence were not analyzed.

Criteria for selecting antibiotic intramammary tubes

Efficacy of different antimicrobial substances

The aim of treatment with an antibiotic is to eliminate the causative pathogen. This can be measured by the BC, which is defined as the absence of the mastitis-causing pathogen in samples taken after treatment. Other indicators for treatment success can be the clinical cure, the cytological cure, recurrent cases of mastitis, and the overall cure. Clinical cure is defined as the absence of clinical symptoms after treatment. The cytological cure is based on the somatic cell count (SCC) and is defined as a reduction in SCC in the samples after treatment below 200,000 cells/ml. Since antibiotics can influence the growth and survival of bacteria, it makes sense to use the BC rate. In practice, this can only be assessed with the aid of bacteriological diagnostics before and after treatment, which means an increase in effort. BC correlates to some degree with clinical cure, which is generally more visible and easier to detect than BC. For this reason, cure after therapy is often assessed based on clinical cure, which is only partly dependent on BC. There are currently no randomized clinical trials that show significant differences in efficacy, i.e., in the achievable bacteriological or clinical cure rates, between the individual udder injectors available in Germany (a literature search was conducted in PubMed and on the Web of Science platform (www.webofknowledge.com) for publications from 2015-2025 using the following terms: [[mastitis OR udder infection OR bovine mastitis] AND [treatment OR therapy OR RCT]. The search was conducted on July 20, 2025 ("cut-off date")). Therefore, the decision for or against an antibiotic injector for the treatment of mastitis should be based on other criteria, such as the resistance profile, the number of doses, the frequency of application (once daily or twice daily), the active ingredient (critical yes/no; one or more active ingredients), withdrawal period, and treatment costs (Table 1).

Critically important substances

There are two classification systems that categorize antibiotics according to their active ingredients. The World Health Organization (WHO) classifies active substances according to their importance for human medicine based on two criteria. Criterion 1: They are one of the few available or even the only therapy for treating serious bacterial infections in humans and Criterion 2: They are used to treat infections that can be transmitted to humans from the environment or other non-human sources or can acquire resistance genes from these sources. Based on these criteria, the active substances are classified as important, highly important, and critically important [18].

According to the system published by EMA, antibiotics are divided into 4 different categories (category A, B, C, and D). Category D ("Prudence") agents are considered as the first choice. If there is no active substance in this category that is effective for the particular case, a category C ("Caution") active substance can be used, for which there are usually alternatives in human medicine. The next category B ("Restrict") includes quinolones, third and fourth generation cephalosporins, and polymyxins. These active substances are also classified as critical active substances for human medicine. They should be used based on susceptibility testing. Preparations that are currently not approved for use in veterinary medicine in Europe are listed in Group A ("Avoid") [19].

According to a survey from 2022 by Preine et al., antimicrobial preparations with a combination of cefalexin/kanamycin and amoxicillin/ clavulanic acid/prednisolone were used most frequently for the local treatment of mastitis in Germany [20]. However, critical active substances, e.g., from the third and fourth generation cephalosporins and fluoroquinolone groups, are still used on German dairy farms [20,21]. But the results from Preine et al. also showed that 57% of the farmers refuse the use of antibiotics in category B [20].

Since 2022, the Regulation (EU) 2019/6 applies to veterinary medicinal products in the European Union. Germany adopted a Veterinary Medicinal Products Act (TAMG) as an independent law, the implementation of which influences the therapy selection for dairy cattle by the parameter "treatment frequency" since 1. January 2023. To calculate this, the number of animals treated for a type of application is multiplied by the number of treatment days for each antibiotic active substance used and divided by the average number of animals kept per half-year (TAMG, § 57 Determination of treatment frequency [22]).

In addition to the number of animals treated and the number of treatment days, the selection of active substances or preparations is an important factor in the calculation. For critically important substances, such as cefquinome (4th generation cephalosporin), each treatment day is multiplied by a factor of three.

Until March 2026, antimicrobial preparations with two or more active substances also massively increased the number of antibiotic doses used in a farm because the figures determined were added for all active substances (in each case). As a result, combination products with more than one active substance were increasingly unattractive from the user's point of view. This provision was removed with the amendment to the TAMG in March 2026. Nevertheless, there are no studies that show significantly higher cure rates when using combination products.

Resistance profile

Antibiotic resistance is a global problem affecting humans and animals. The treatment of clinical bovine mastitis with antimicrobial agents is frequently induced without prior knowledge of causative agents [21] and preferred use of antimicrobials covering a broad spectrum of pathogens [20]. Systematic resistance monitoring is a prerequisite for early detection of changes in the antimicrobial susceptibility of pathogens. In most cases, retrospectively obtained data on the resistance situation of mastitis pathogens on dairy farms is used for decision-making. The SPCs (Summary of product characteristics) of the products recommend that the use of the products should be based on susceptibility testing of the bacteria isolated from the animal. If this is not possible, therapy should be based on local (regional and farm level) epidemiological information about susceptibility of the target bacteria, as well as by taking into account official national antimicrobial policies. For most mastitis pathogens that can be influenced by antibiotic therapy, the lowest resistance rates are to be expected with simple beta-lactam antibiotics [23].

Soft criteria

In practice, decisions are not always made on the basis of evidence. They are often based on different personal experiences, preferences, or operational processes. A survey of German dairy farmers showed that a good experience with a product was the most important aspect for the 99 farmers surveyed when it came to the prescription of udder tubes by the veterinarian (90.8% stated "very important" and "important"). Furthermore, 40.8% of the farmers surveyed stated that they preferred a treatment frequency of 24 hours [20].

Milk Science International (79) 2026 P. 1-7
ISSN 2567-9538; https://doi.org/10.48435/MSI.2026.1

Table 1: A variety of criteria that can be taken into account when deciding for or against an antibiotic product for local mastitis therapy.

Criteria	Source/assumption/calculated
critical active ingredient (yes/no) (according to EMA 2020, category B)	Source: SPCs [1]
active ingredient	Source: SPCs
withdrawal period for meat and offal (d)	Source: SPCs
withdrawal period for milk (d)	Source: SPCs
frequency of application (if available: min. and max.)	Source: SPCs
time interval between the applications (12h, 24h or 48h)	Source: SPCs
discarded milk yield during withdrawal period (kg ECM[2] per day)	assumption: 30kg ECM milk per day (DIM[3] were not considered)
milk price (€/kg)	assumption: 0,5€/kg (Rohstoffwert Milch, IFE Kiel, Price July 2025 0.50€/kg) https://www.lwk-rlp.de/markt-statistik/marktbericht/marktbericht/rohmilch-1
treating personnel's hourly wage (€/h)	assumption: 20€/h
treatment duration (d)	calculated: min. frequency of application x time interval between the applications (in days)
time interval in a sick pen (d)	calculated: treatment duration (d) + withdrawal period for milk (d)
workload for applications (h)	calculated: min. frequency of applications x 0.17h [10]
costs per injector (€)	calculated: cost for one package / number of injectors per package (Anonymous, Lila Liste, 2023)
costs for applications (€)	calculated: hourly wage x workload for applications
costs for discarded milk yield during withdrawal period (€)	calculated: time interval in a sick pen (d) x discarded milk yield during withdrawal period (kg ECM per day) x milk price (€)
costs per treatment session for medication (€)	calculated: cost per injector x min. frequency of applications
summarized costs for applications and discarded milk (€)	calculated: costs for applications + costs for average discarded milk yield during withdrawal period
costs due to antibiogram requirement (€)	assumption: including sampling, packaging, shipping, analysis (bacteriology and antibiogram), reports
total costs per case (€)	calculated: costs for applications + costs for discarded average milk yield during withdrawal time + costs per treatment session for medication

[1] Summary of Product Characteristics, [2] energy-corrected milk, [3] days in milk.

Economics

Mastitis is still one of the most cost-intensive diseases on dairy farms. These costs arise from a variety of factors and can be divided in direct costs, such as expenses for medication, diagnostics, and the veterinarian, costs for extra work, and indirect costs, due to waste milk, milk yield losses, and costs for replacement because of an increased culling rate. Even though the indirect costs are considerably higher [24,25,26], therapeutic costs are the costs that are most visible to farmers and are therefore often cited as the most important factor when it comes to making a treatment decision [27].

Therefore, we calculated the total direct cost of treating one case of CM for all antibiotic udder injectors with market relevance listed in the Lila Liste [28] for Germany. We assume that any costs incurred for clinical diagnosis by veterinarians will be the same and therefore do not need to be taken into account, and that treatments carried out by farmers will be supervised and guided by veterinarians in accordance with applicable law.

For the following analysis and calculation of costs, various data were compiled or calculated, and assumptions were made for the typical udder injectors used in Germany (Table 1). Information for the individual injectors on the withdrawal time for meat and milk, the frequency of application, the time interval between applications, the active ingredient, and whether it contains a critical active substance was taken from the SPCs.

Assumptions were made in the calculation to be able to present these comparatively. These relate to the average daily milk yield of the treated animals, the sales price per liter of milk, the assumed labor costs per hour, and an estimate of the time required for treatment. The latter was determined in an earlier study (10 minutes (0.17 h) per treatment, including the associated documentation) [29].

Economic calculation

Costs of different injectors: To calculate the cost of a single injector, the price of a pack of medication was divided by the number of intramammary injectors per pack. The costs per treatment session for medication were calculated from the cost of a single injector multiplied by the frequency of applications [28].

The selection of injectors was based on the products with market relevance listed in the Lila Liste [28] an established pharmaceutical reference in Germany (prices retrieved on April 1, 2026). This reference reflects the products of practical market relevance rather than the complete set of all marketing authorisations. Accordingly, the analysis covers the udder injectors listed in this reference and does not claim to include every preparation authorised in Germany.

Extra work: The costs for applications were calculated by multiplying the assumed treating personnel's hourly wage and the calculated workload for applications. The workload for applications of udder tubes was calculated by multiplying the minimum number of applications and the assumed time required for each application (including documentation and sampling if necessary) of 0.17 h. A value of €20 per hour was assumed as the hourly wage for the treating personnel.

Discarded milk: The time interval during which a diseased cow is in a sick pen, i.e. the time that includes treatment and withdrawal period, was calculated by the addition of the treatment duration in days and the respective withdrawal time for milk. It was assumed that about 30 kg of ECM (energy-corrected milk) would be discarded per day during the withdrawal time as a result of the treatment. The milk from cows with CM is altered and therefore cannot be delivered. However, as most mild and moderate cases are clinically cured after 5 days, and this is within the withdrawal period, this fact does not need to be considered. The milk price was assumed to be 0.5 €/kg in line with the current situation. Multiplying the calculated time interval (d), the discarded milk yield (kg) during treatment and withdrawal period, and the milk price (€/kg), the costs for discarded milk yield per mastitis episode were calculated. At the moment, milk with antibiotic residues is disposed of in manure on most farms. This practice may change in the future to avoid contamination of the soil with antibiotic residues. In this case, the milk with residues would have to be disposed of for a fee (incineration).

Frequency of application: The summarized costs for application and discarded milk are the amount of the costs for application and the costs for discarded milk yield during withdrawal time.

To calculate the total cost, the costs for discarded milk were then added to the costs for applications and the costs per treatment session for medication. If the preparation contains a critical active ingredient and is therefore subject to the antibiogram requirement according to current legislation, the costs for the preparation of an antibiogram (including sampling, transport, and analysis) were added to the total costs.

Results of the economic calculation

In Germany, 14 udder injectors with antimicrobial agents for treatment of CM in dairy cows and with market relevance are listed in the Lila Liste (Table 2), out of which three contain a critical active ingredient (Cobactan® LC 75mg, Qivitan LC 75mg, Selecef 75mg, EMA category B). The withdrawal period for meat varies between 3 days (Ubropen®, Gelstamp®, and Albiotic intramammär®) and 10 days (Ubrolexin®). For milk, the withdrawal period varies between 3 days (Gelstamp® and Rilexine®200LC) and 6 days (Ubropen®, Veyxid® Pen-Proc 3 Mega, Procain-Penicillin-G Injektor aniMedica®, and ProPen 3000®). Among the products, more than half of them (n=9) require a minimum of 3 doses, while three products require 2 doses, and only two products need to be given four times. Five products are given once daily (time interval of 24 hours between applications) and eight products twice daily, while one product is applied every 48 hours (Orbenin® LA). A product has a registration for prolonged therapy of S. aureus (Synulox® LC Plus).

The time interval in a sick pen, which refers to the time during which a treated cow is excluded from milk production, varies between 4.5 days (Gelstamp®) and 10 days (Orbenin® LA). The workload for applications is highest for Mastiplan® LC and Rilexine® with 0.68h and lowest for Ubrolexin ®, Veyxid® Pen-Proc 3 Mega and ProPen 3000® with 0.34h. Among these products, Mastiplan® LC and Rilexine® are also the products with the highest costs for applications of 13.60€, while Ubrolexin®, Veyxid® Pen-Proc 3 Mega, and ProPen 3000® have the lowest costs for applications of 6.80€.

The lowest costs for discarded milk yield during withdrawal time were determined for Gelstamp® with 67.50€ and for Synulox® LC Plus, Albiotic® intramammär and Rilexine® with 75.00€, which is mainly due to a short withdrawal time. Highest costs for discarded milk yield during withdrawal period were determined for Orbenin® LA with 150.00€. In terms of injector prices, Veyxid® Pen-Proc 3 Mega and Pro Pen 3000® are the cheapest with 2.16€ and 2.27€ per injector, followed by Procaine-Penicillin-G Injektor aniMedica® with 2.68€ per injector, while Ubropen® is the most expensive with 7.27€ per injector. The cost per treatment session for medication is highest for Rilexine® with 23.20€ followed by Ubropen® with 21.81 and Synulox® LC Plus with 19.11€ and lowest for Veyxid® Pen-Proc 3 Mega and Pro Pen 3000® with 4.32€ and 4.54€. Although Rilexine®200 LC and Synulox® LC Plus are among the injectors with the highest cost per treatment session for medication, the total costs are relatively low with 104.31€ for Synulox® LC Plus and 111.80€ for Rilexine®200LC due to the short time in a sick pen. Gelstamp® has the lowest total costs with 96.00€ followed by Albiotic® intramammär with 102.39€.

Discussion

The treatment of mastitis in dairy cows is a critical aspect of herd health management, and the selection of appropriate antibiotic preparations is important to achieve effective results.

Efficacy of different antimicrobial substances

The primary goal of antibiotic treatment must always be to achieve the highest possible BC rate. This aspect should be decisive when deciding for or against an antibiotic injector. However, there are currently no studies that show relevant significant differences in efficacy, i.e. in the achievable BC rates, between the individual injectors. Recently, Leon et al. have not found significant differences on BC rate and clinical cure between cefquinome and amoxicillin and clavulanic acid [30].

In general, antibiotic treatment for mastitis should follow current guidelines and the SPC. This includes, for example, initial selection based on microbiological findings or on-farm tests, regular resistance testing, ensuring hygienic administration, and monitoring treatment outcomes [31].

In addition, in many farms, the choice of preparation is instead made on the basis of undocumented experience of clinical cure after application [21]. This approach is not evidence-based and should be replaced by comprehensible approaches. For this reason, further studies comparing different therapeutics for mastitis treatment are required to ensure that there are no differences in efficacy. However, there are other aspects that are relevant in the decision-making process.

Critical important substances

The entry into force of the changes of the TAMG also influences farmers' and veterinarians' decisions. Avoiding critical active ingredients and extended treatments is particularly important in the decision-making process on dairy farms with relatively high treatment frequencies. Farms with a high number of treated animals with this type of application try to minimize the treatment days to avoid conflicts with the competent authority and accept higher costs for the treatment. Based on the available data and subject to the selection of controllable intramammary infections and any resistance problems, optimal mastitis tubes/injectables for mild and moderate mastitis are those that contain a non-critical active ingredient and have a short withdrawal time for milk. These products should be the first choice. Further optimization can be achieved by using on-farm tests beforehand that identify Gram-positive infections and determine penicillin sensitivity.

Resistance profile

The resistance profile of mastitis pathogens is a critical consideration in the selection of antibiotics. The data published in Germany on the resistance situation of mastitis pathogens does not show any particular resistance developments [32]. Nevertheless, epidemiological studies, continuous monitoring and reporting are essential to detect and respond to any emerging resistance patterns. Based on the available data, the differences between the various beta-lactam antibiotics are very small [23]. In individual cases, beta-lactamase-resistant antibiotics or an effectiveness against Klebsiella spp. may be indicated.

Milk Science International (79) 2026 P. 1-7
ISSN 2567-9538; https://doi.org/10.48435/MSI.2026.1

Table 2: Results for the udder injectors available in Germany on the investigated criteria that can be taken into account when deciding for or against an antibiotic product.

Antibiotic agent	**Ubropen®**	**Ubrolexin®**	**Mastiplan® LC**	**Synulox® LC Plus**	**Veyxid® Pen-Proc 3 Mega**	**Procain-Penicillin-G Injektor aniMedica®**	**Pro Pen 3000®**	**Orbenin® LA**	**Gelstamp®**	**Albiotic® intramammär**	**Rilexine® 200 LC**	**Cobactan® LC 75mg**	**Qivitan LC 75mg**	**Selecef 75mg**
company	Boehringer Ingelheim	Boehringer Ingelheim	MSD	Zoetis	Veyx	Livisto	Livisto	Zoetis	Zoetis	Huevepharma	Virbac	MSD	Livisto	Selectavet
active ingredient	benzylpenicillin-procaine 600 mg	cefalexine 200mg + kanamycin 100,000 I.U.[1]	cefapirin 300mg, prednisolone 20mg	amoxicillin 200mg, clavulanic acid 50mg, prednisolone 10mg	benzylpenicillin-procaine 3g	benzylpenicillin-procain 300mg	benzylpenicillin-procaine 3g	cloxacillin 200mg	ampicillin 79.7mg, cloxacillin 218.4	lincomycin 330mg, neomycin 100mg	Cefalexin 200mg	cefquinome 75mg	cefquinome 75mg	cefquinome 75mg
critical active ingredient (yes/no)	no	no	no	no	no	no	no	no	no	no	no	yes	yes	yes
EMA categorization	D	C+C	C	C	D	D	D	D	D+D	C+C	C	B	B	B
broad/small spectrum (B/S)	S	B	B	B	S	S	S	B	B	B	B	B	B	B
WT Me[2](d)	3	10	4	7	5	5	5	7	3	3	4	4	4	4
WT Mi[3](d)	6	5	5.5	3.5	6	6	6	4	3	3.5	3	5	5	5
application min.	3	2	4	3	2	3	2	3	3	3	4	3	3	3
application max.	5				3		3							
Treatment duration (d)	3	2	2	1.5	2	3	2	6	1.5	1.5	2	1.5	1.5	1.5
time interval between the applications (h)	24	24	12	12	24	24	24	48	12	12	12	12	12	12
discarded milk yield during withdrawal time (kg ECM[4] per day)	30	30	30	30	30	30	30	30	30	30	30	30	30	30
milk price (€/kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
treating personnel's hourly wage (€)	20	20	20	20	20	20	20	20	20	20	20	20	20	20
time interval in a sick pen (d)	9	7	7.5	5	8	9	8	10	4.5	5	5	6.5	6.5	6.5
workload for applications (h)	0.51	0.34	0.68	0.51	0.34	0.51	0.34	0.51	0.51	0.51	0.68	0.51	0.51	0.51
costs per injector (€)	7.27	6.73	4.30	6.37	2.16	2.68	2.27	5.83	6.10	5.73	5.80	5.56	6.23	3.29
costs for applications (€)	10.20	6.80	13.60	10.20	6.80	10.20	6.80	10.20	10.20	10.20	13.60	10.20	10.20	10.20
costs for discarded milk yield during withdrawal time (€)	135.00	105.00	112.50	75.00	120.00	135.00	120.00	150.00	67.50	75.00	75.00	97.50	97.50	97.50
costs per treatment session for medication (€)	21.81	13.46	17.20	19.11	4.32	8.04	4.54	17.49	18.30	17.19	23.20	16.68	18.69	9.87
summarized costs for applications and discarded milk (€)	145.20	111.80	126.10	85.20	126.80	145.20	126.80	160.20	77.70	85.20	88.60	107.70	107.70	107.70
costs due to antibiogram requirement[5]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	25.00	25.00
Total costs (€)	167 -218	125.26	143.30	104.31	131-152	153.24	131-152	177.69	96.00	102.39	111.80	149.38	151.39	142.57

[1] international unit, [2] withdrawal period for meat and offal, [3] withdrawal period for milk, [4] energy-corrected milk, [5] including sampling, transport, analysis.

ISSN 2567-9538; https://doi.org/10.48435/MSI.2026.1

Soft criteria

However, the economy is often not the prevailing reason for the farmers' and veterinarians' decision for or against an injector. Farmers sometimes do not calculate the total costs for a treatment session, so their considerations for or against an injector may be distorted and influenced by other arguments, getting more weighting because the costs for the injectors seem to be quite similar. So soft criteria become more important. An administration only once a day promises less costs for injectors or less work for the application and better management. An increasing number of dairy farms are employing external workers, most of whom are only moderately trained and often have language difficulties. For this reason, many farms aim to have antibiotics administered only once a day by specialized personnel. Even on dairy farms with milking robots, limiting treatment to once a day can facilitate the treatment of mastitis. For this reason, some farms prefer to use antibiotic udder tubes which only need to be applied once a day.

Economics

If the decision for or against an antimicrobial injector is made on the basis of economy, preparations with a short withdrawal period in milk are always economically advantageous. While certain injectors may incur higher costs per treatment session for medication, their shorter withdrawal times and lower milk production losses can bring overall cost savings to dairy farms. Costs associated with milk discard are an important determinant of CM costs. In our analysis, they accounted for an average of about 80% of the total direct costs of treatment (costs for discarded milk yield during withdrawal period).

Oliveira and Ruegg (2014) expected a 5-days-period of abnormal milk after a CM episode [33]. Abnormal milk may not be sold for human consumption, and milk from cows receiving antibiotics must be discarded for prescribed withdrawal periods. If this milk is fed to calves and thus possible costs are reduced by milk replacer, this area accounts for 5.7% of the total costs per clinical case of mastitis.

However, if this milk is not used but discarded instead, the share of total costs increases to 22% [27]. Thus, increased monetary losses are associated with longer durations of treatment [3]. For example, expected monetary losses of CM were estimated to increase from approximately $65 to $187 per case as treatment days increased from 2 to 8 d [3].

In principle, the veterinary practice in charge is of course responsible for selecting the preparation. However, farmers and milking staff are often involved in deciding which preparation to use [21]. That's why the decision-making process should be carried out in cooperation between all people involved, including veterinarians, farmers, and milking staff.

Limitations of the study

This study has some limitations. Even though many criteria for the selection of an injector were included, one substantial criterion was not considered: the BC rate. The main object of treatment with an antibiotic is to eliminate the causative pathogen, expressed by the BC. The other criteria should only be supporting criteria. But because of the absence of studies that show any significant differences in cure rates between the individual injectors, other criteria are coming to the fore. A further limitation concerns the selection of products: the analysis was based on the udder injectors listed in the Lila Liste and therefore does not cover every preparation authorised for the treatment of CM in Germany.

Conclusion

The most important criteria when selecting an antibiotic udder injector for label use should be a high expected BC rate and the absence of resistance to the antimicrobial substance. As knowledge of the BC rate and the resistance situation can usually only be obtained after the therapy, decisions for or against an appropriate product are made on the basis of rather soft criteria. Decisions based on soft criteria, such as ease of administration (e.g., once-a-day treatments), can be more appealing to farms with external workers or those using milking robots. These criteria, while not directly related to efficacy, can heavily influence the choice of antibiotic injectors. As there is a lack of comparative studies on existing udder injectors, it is not possible to make a reliable comparative assessment of their efficacy, i.e. in the achievable BC. The overarching consequence for veterinarians is the need to balance multiple factors, including cost, convenience, regulatory compliance, and antibiotic resistance, in their treatment decisions. There is currently a lack of evidence-based support for products containing multiple antibiotic active ingredients, as well as for formulations that include critically important active substances. Therefore, the choice of a preparation should be guided by its practical applicability and cost-effectiveness. The use of on-farm diagnostic test systems can support this decision-making process, as they allow for the identification of the pathogen group and the assessment of penicillin resistance.

Disclosure of conflicts of interest

Luis Leon works as Medical Lead for Zoetis Germany, a company that also manufactures and distributes antibiotic udder injectors.

References

1. Van Werven T. Managing Dairy Cows with Less Antibiotics! WCDS Advances in Dairy Technology (2018) Volume 30: 37-47.
2. Kortstegge, J., Persson Waller, K., Scherpenzeel, C., Starič, J., Pínho, L., Kovacs, P., Salat, O., Biggs, A., Moroni, P., & Krömker, V. Different European perspectives on the treatment of subclinical mastitis in dairy cows. Milk Science International, 2024;77(2). Doi:10.48435/MSI.2024.2.
3. Pinzón-Sánchez C, Cabrera VE, Ruegg PL. Decision tree analysis of treatment strategies for mild and moderate cases of clinical mastitis occurring in early lactation. J Dairy Sci. 2011;94(4):1873-92. doi: 10.3168/jds.2010-3930.
4. Fuenzalida MJ, Fricke PM, Ruegg PL. The association between occurrence and severity of subclinical and clinical mastitis on pregnancies per artificial insemination at first service of Holstein cows. J Dairy Sci. 2015;98:3791–3805. doi:10.3168/jds.2014-8997.
5. Ruegg PL. Making Antibiotic Treatment Decisions for Clinical Mastitis. Vet Clin North Am Food Anim Pract. 2018;34(3): 413-425.
6. Krömker V, Leimbach S. Mastitis Treatment-Reduction in antibiotic usage in dairy cows. Reprod Dom Anim. 2017; 52(Suppl. 3): 21-29. doi:10.1111/rda.13032.
7. Wilm J, Krömker V, Kirkeby C, Gussmann M. Lactational treatment of bovine mastitis-Development over time and factors influencing cytological cure. J Dairy Sci. 2023;106(8):5740-5752. doi: 10.3168/jds.2022-22841.
8. Schmenger A, Leimbach S, Wente N, Zhang Y, Biggs AM, Krömker V. Implementation of a targeted mastitis therapy concept using an on-farm rapid test: antimicrobial consumption, cure rates and compliance. Vet Rec. 2020;187(10):401. doi:10.1136/vr.105674.
9. de Jong E, Creytens L, De Vliegher S, McCubbin KD, Baptiste M, Leung AA, Speksnijder D, Dufour S, Middleton JR, Ruegg PL, Lam TJGM, Kelton DF, McDougall S, Godden SM, Lago A, Rajala-Schultz PJ, Orsel K, Krömker V, Kastelic JP, Barkema HW. Selective

Milk Science International (79) 2026 P. 1-7
ISSN 2567-9538; https://doi.org/10.48435/MSI.2026.1

treatment of nonsevere clinical mastitis does not adversely affect cure, somatic cell count, milk yield, recurrence, or culling: A systematic review and meta-analysis. J Dairy Sci. 2023;106(2):1267-1286. doi: 10.3168/jds.2022-22271.
10. Krömker V: MastDecide + - der nächste Schritt in der Mastitisbekämpfung 10. Leipziger Tierärztekongress 2020.
11. European Medicines Agency (EMA). Categorisation of antibiotics in the European Union. EMA/CVMP/CHMP/682198/2017. 12 December 2019. https://bit.ly/30ZEuRi.
12. Hillerton JE, Kliem KE. Effective treatment of Streptococcus uberis clinical mastitis to minimize the use of antibiotics. J Dairy Sci. 2002;85(4):1009-14. doi:10.3168/jds.S0022-0302(02)74161-1.
13. Svennesen L, Skarbye AP, Farre M, Astrup LB, Halasa T, Krömker V, Denwood M, Kirkeby C. Treatment of mild to moderate clinical bovine mastitis caused by gram-positive bacteria: A noninferiority randomized trial of local penicillin treatment alone or combined with systemic treatment. J Dairy Sci. 2023;106(8):5696-5714. doi: 10.3168/jds.2022-22993.
14. Wenz JR, Barrington GM, Garry FB, et al. Bacteremia associated with naturally occurring acute coliform mastitis in dairy cows. J Am Vet Med Assoc. 2001;219(7):976–81.
15. Brennecke J, Falkenberg U, Wente N, Krömker V. Are Severe Mastitis Cases in Dairy Cows Associated with Bacteremia? Animals (Basel). 2021;11(2):410. doi: 10.3390/ani11020410.
16. Krebs I, Zhang Y, Wente N, Leimbach S, Krömker V. Bacteremia in Severe Mastitis of Dairy Cows. Microorganisms. 2023;11:1639. doi:10.3390/microorganisms11071639.
17. Schmenger A, Krömker V. Characterization, Cure Rates and Associated Risks of Clinical Mastitis in Northern Germany. Vet Sci. 2020;7(4):170. doi:10.3390/vetsci7040170.
18. World Health Organization (WHO). Critically Important Antimicrobials for Human Medicine. 6th Revision 2018. Version 22.03.2019. https://apps.who.int/iris/rest/bitstreams/1217095/retrieve.
19. European Medicines Agency (EMA). Categorisation of Antibiotics Used in Animals Promotes Responsible Use to Protect Public and Animal Health. 28.01.2020, EMA/688114/2020.
20. Preine F, Schmenger A, Leon L, Krömker V. Status quo und Perspektiven der lokalen antibiotischen Mastitisbehandlung: eine Umfrage unter Landwirten in Deutschland. Der Praktische Tierarzt. 2022;103:1258–1268.
21. Falkenberg U, Krömker V, Heuwieser W, Fischer-Tenhagen C. Survey on routines in udder health management and ther-apy of mastitis on German dairy farms. Milchwissenschaft - Milk Sci Int. 2019;72:11–15.
22. TAMG (Tierarzneimittelgesetz), Veterinary Medicinal Products Act of 27 September 2021. Federal Law Gazette (Bundesgesetzblatt) I, p. 4530, last amended by Article 1 of the Ordinance of 14 March 2024, Federal Law Gazette 2024 I No. 97.
23. Bolte J, Zhang Y, Wente N, Krömker V. In Vitro Susceptibility of Mastitis Pathogens Isolated from Clinical Mastitis Cases on Northern German Dairy Farms. Vet Sci. 2020;7(10). 10. doi:10.3390/vetsci7010010.
24. Huijps K, Lam TJ, Hogeveen H. Costs of mastitis: facts and perception. J Dairy Res. 2008;75(1):113-20. doi:10.1017/S0022029907002932.
25. Kossaibati MA, Esslemont RJ. The costs of clinical mastitis in UK dairy herds. Cattle Pract. 2000; 8:323–327.
26. Leite de Campos J, Gonçalves JL, Kates A, Steinberger A, Sethi A, Suen G, Shutske J, Safdar N, Goldberg T, Ruegg PL, Variation in partial direct costs of treating clinical mastitis among 37 Wisconsin dairy farms, J Dairy Sci. 2023;106(12):9276-9286. doi:10.3168/jds.2023-23388.
27. Rollin E, Dhuyvetter KC, Overton MW, The cost of clinical mastitis in the first 30 days of lactation: An economic modeling tool. Prev Vet Med. 2015;122(3): 257-264. doi:10.1016/j.prevetmed.2015.11.006.
28. Anonymous. Lila Liste. 38. Aufl. Wissenschaftliche Verlagsgesellschaft Stuttgart 2023 ISBN 978-3-8047-4452-3.
29. Krömker V: Mastitiskalkulator – ein Berechnungstool zur Kostenanalyse im Bestand. In: Ökonomie der integrierten tierärztlichen Bestandsbetreuung (ITB) im Rahmen von Qualitätsmanagementsystemen (QMS), Kongress des Bundesverbandes praktischer Tierärzte 2000, Leipzig, 11-15.10.2000.
30. Leon L, Fidelak C. Field study comparing two intramam-mary antibiotics for the treatment of bovine clinical mastitis. In: World Buiatrics Congress - Mexico 2024 by World Association for Buiatrics.
31. German Veterinary Association (GVA) 2026. Guidelines for Mastitis Control in Dairy Herds [Leitlinien zur Bekämpfung der Mastitis des Rindes als Bestandsproblem]. https://www.dvg.de/wp-content/uploads/2026/05/07_26-05-04_AG-Euter_250423Leitlinien-Kapiteldatei_Mastitistherapie.pdf.
32. Leimbach S, Nankemann F, Tellen A, Klocke D, Wente N, Zhang Y, Krömker V. Retrospective Analysis of Penicillin G Minimum Inhibitory Concentration for Gram-Positive Isolates of Non-Severe Clinical Mastitis. Antibiotics. 2025; 14(1):21. doi:10.3390/antibiotics14010021
33. Oliveira L, Ruegg PL, Treatments of clinical mastitis occurring in cows on 51 large dairy herds in Wisconsin, J Dairy Sci. 2014;97(9): 5426-5436, ISSN 0022-0302, doi:10.3168/jds.2013-7756.