

Sustainable Use of Antibiotics at Dry-off in Dairy Cows

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The development work includes a procedure for selecting dairy cows for ATB/noATB (ATB = antibiotic(s)) dry-off treatment based on the dynamics of somatic cell count (SCC). This can reduce the use of ATB in mastitis prophylaxis. Milk secretion disorders are consistently one of the main sources of losses in milk production and quality and the use of ATB to treat dairy cows. The increased use of ATB generally results in an increase in the risk of bacterial pathogens developing resistance to these ATB. Suitable dairy cows are selected for noATB dry-off based on favorable SCC development. In total, 29.1 (Holstein (H)), 14.8 (H), 21.0 (Czech Fleckvieh (CF)) and 14.4 (CF) % of cows were proposed for dry-off without ATB and 70.9 (H), 85.2 (H), 79.0 (CF) and 85.6 (CF) % with ATB in 4 randomly selected herds of cows. This is in total $19.8 \pm 6.9\%$ (v_x 34.8%) noATB and $80.2 \pm 6.9\%$ (v_x 8.6%) ATB. This proportion $80.2 \pm 6.9\%$ appears, from the perspective of the objective of procedure validation, to be higher than would be necessary. This indicates the need for a more moderate correction of the selection criteria. The methodology is innovative as it presents known facts in new contexts. The methodology represents an advantageous connection of an older husbandry measure, which is milk recording, with the health and quality management of the dairy herd. This can increase the efficiency of dairy farming and the safety of the milk food chain.

Keywords: milk indicator dynamics, breed, milk recording, subclinical mastitis, linear somatic cell count score

1 Introduction

Mastitis is the most important production infectious disease in dairy cows, especially subclinical form. The above-mentioned is determined primarily by economic losses due to the occurrence of mastitis (Atasever and Erdem, 2009; Kvapilík et al., 2014, 2015; Arian et al., 2024; Stanek et al., 2024). The other factors are also given by the aspect of dairy cow health, deterioration of milk quality and increased consumption of antibiotics in treatment and prophylaxis of mastitis (Pyörälä, 2003; Pitkälä et al., 2004; Ruegg, 2017; Niemi et al., 2022). Hisira et al. (2024) mentioned that "Despite the considerable efforts made by many scientists and experts in mastitis, the disease has not been eliminated on dairy farms and remains a serious problem, causing significant losses to farmers." Kvapilík et al. (2014, 2015) published an estimate of economic losses due to mastitis in primary milk production in the Czech Republic. The total loss per

case of mastitis (clinical and severe subclinical mastitis) was estimated at CZK 9,000. However, due to inflation, this item can now be around CZK 11,700. The main loss was caused by reduced milk yield, 37% (Figure 1). Arian et al. (2024) mentioned that the total economic

loss in subclinical mastitis, as the main cause of losses in the herd, is not only due to the loss of milk production, but also to the cost of treatment and the loss of milk from the cow in the case of antibiotic treatment. They estimated this volume at 41.15, 80.5 and 114.5 l of milk per treatment in cases of mild, moderate and severe disease, respectively. Furthermore, Atasever and Erdem (2009) recorded in Holstein cows in Turkey with an average somatic cell count (SCC) for 10 years of $705 \cdot 10^3 \cdot \text{ml}^{-1}$ relative losses in daily milk yield, lactation milk yield and milk yield for 305 days of lactation of 14.6 to 17.4, 11.6 and 12.8 to 15.4%.

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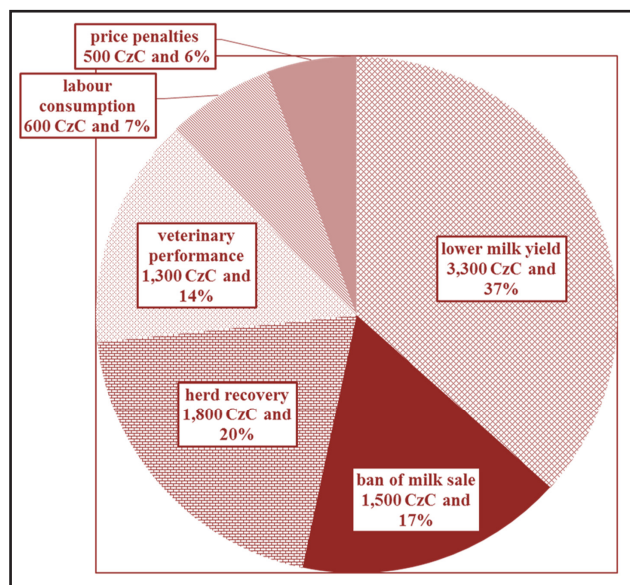


Figure 1 Structure of costs and losses caused by mastitis in the CR (per case, 100% = CZK 9,000). Reproduced (unchanged) from Kvapilík et al. (2015), *Bulgarian Journal of Agricultural Science*, © Agricultural Academy. Licensed under CC BY 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

In medicine, the overuse of antibiotics (ATB) has previously been noted in general in the treatment of diseases (humans and animals), but also in dairy farming. It was especially in the case of widespread (100% of cows in the herd) ATB dry cow treatment for a long period of about 30 years. This took place as part of commercially-conventional mastitis prophylaxis, in most developed dairy countries, including the Czech Republic (in almost all dairy herds). As a result of this fact, there has been a general increase in the resistance of pathogenic bacteria over time (Wilhelm et al., 2009; Boireau et al., 2018; Roope et al., 2019; Alenezi et al., 2024). This serious medical problem of threatening the effectiveness of the treatment of infectious diseases is the reason for the general requirement to reduce the ATB use (Singleton et al., 2020; Fleischer et al., 2024; Pechová et al., 2024; Regulation of the European Parliament and of the Council EU 2019/6, 2019/4, Commission Regulation EU 2021/1760). The goal is to make ATB therapeutic application more efficient and thus limit the risk of the growth of bacterial resistance. In dairy farming, it is then possible to achieve a reduction in the consumption of ATBs by several methods:

- early diagnosis of subclinical mastitis;
- control of high milking hygiene and the use of disinfectant dipping of teats before and after milking;
- carrying out antimastitis vaccination of cows (Mašek et al., 2022).

Furthermore, it can be the selection of dairy cows for ATB dry cow treatment according to various criteria such as:

- the result of the mastitis test before dry-off;
- the value of the height and variability of milk yield at the end of lactation;
- the result of farm bacterial cultivation before dry-off;
- the result of the SCC during and at the end of lactation (Fleischer, 2023; Fleischer et al., 2024; Pechová et al., 2024).

The SCC has been a hygienic and health indicator of raw milk quality for a long time. It is for about 70 years since the time of the first viscosogenic tests with the addition of detergents to milk and the manifestation of the so-called Schalm reaction in bulk tank (milk quality control) and individual (milk recording (MR)) samples. With the development of flow cytometry (FC) for SCC determination, the reliability of the results has increased. With the automation of the FC devices, the hourly measurement performance has increased to today's approximately 500/hour. SCC serves primarily as an indicator of subclinical (mainly infectious, but also non-specific) mastitis, and EU food legislation limits this indicator for standard milk ($\leq 400 \cdot 10^3 \cdot \text{ml}^{-1}$; Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004). However, some quality control systems in the world are more benevolent. The SCC of a healthy mammary gland is often strictly limited to $\leq 100 \cdot 10^3 \cdot \text{ml}^{-1}$ (Fleischer, 2023). According to various sources (Reneau et al., 1988; Fleischer, 2023), the indicative level of SCC for subclinical mastitis (or milk secretion disorder) is between $100\text{--}300 \cdot 10^3 \cdot \text{ml}^{-1}$. SCC indicative values for subclinical mastitis may vary depending on the conditions. Over time, with the improvement of analytical methods, the measurement of SCC in dairy farms has significantly expanded in frequency, from bulk tank samples to individual milk samples. SCC values are used not only to control the health of the mammary gland and the level of milking technology. For example this is also to determine the breeding values of bulls (sires) about SCC for the purposes of genetic improvement of dairy cattle. The SCC is a typical health indicator with the absence of a normal frequency distribution (Hanuš et al., 2009) of data and is characterized by a lognormal frequency distribution of data with high variability. This is often well above 100% for individual milk samples, depending on the health of the herd, sometimes even 200 to 300%. As such, SCC is therefore difficult to evaluate and interpret using conventional statistical procedures. Conventional arithmetic means of SCC in classical milk recording may not be suitable mean indicators for mammary gland health databases. Therefore, for effective, practical interpretation of SCC data, various forms of mathematical transformations have been

developed over time (Ali and Shook, 1980; Shook, 1982; Hanuš et al., 2009), for working with the geometric mean (the median is also suitable) instead of the arithmetic mean, but also for obtaining a specific, so-called linear SCC score (SCS; SCC classes increase from 0 to 9 for the full SCC scale, with the subclinical mastitis threshold of $> 283 \text{ } 10^3 \cdot \text{ml}^{-1}$; Reneau et al., 1983, 1988; Reneau, 1986). SCS is particularly notable for linearizing the relationship between SCC increase and milk production losses in dairy cows due to mastitis. SCS also simplifies the handling of SCC data in practice.

The aim of this work was to compare the effectiveness of the procedure and proposed SCC statistical criteria for selecting of dairy cows for antibiotic dry-off according to SCC dynamics during lactation on model records of selected herds of both main dairy breeds in the Czech Republic, in practical milk recording.

2 Material and Methods

2.1 Model Herds of Dairy Cows from Milk Recording

The results of four randomly selected larger dairy herds were extracted from the database of milk recording (MR; Czech Moravian Breeders' Corporation, Inc. (CMBC), guarantor of MR in the Czech Republic). Two herds of the Holstein breed (H; n. 1 and 2) and two herds of the Czech Fleckvieh breed (CF; n. 3 and 4) with above-average milk yield were included. The model herds for validation of the procedure were located at the altitude of 230, 295, 345 and 520 m. The tested period represented one year (in the period 2023–2024) of MR records. The milk yield value and lactation order were also used as milk indicators for the herd characteristics.

2.2 Analytical and Statistical Procedures

Milk samples were measured on analytical equipment according to the relevant standard operating procedures of an accredited laboratory (testing laboratory CMBC 1312.2 accredited by the CIA according to ČSN EN ISO/IEC 17025:2018, Milk Analysis Laboratory (LRM) Brno-Tuřany).

The samples were analyzed for component indicators:

- fat content (F, %);
- crude protein content (CP, %);
- lactose monohydrate content (L, %);
- solids non fat content (SNF, %);
- urea concentration (U, $\text{mg} \cdot 100 \text{ ml}^{-1}$);
- free fatty acid content in milk fat (FFA, $\text{mmol} \cdot 100 \text{ g}^{-1}$ of fat);
- citric acid content (CA, %);
- acetone content (AC, $\text{mmol} \cdot \text{l}^{-1}$).

The analyses were performed on relevantly calibrated and controlled infraanalyzers of milk using the MIR-FT

method (infrared spectroscopy in the mid-infrared region under the conditions of using the spectrum recording by a Michelson interferometer and evaluating the signal recovery by means of Fourier transforms). The instruments used were CombiFoss FT+ (Foss Analytical A/S, Hillerød, Denmark) or Bentley 300 (Bentley Instruments, Chaska, Minnesota, USA). The combined expanded uncertainties of the measurement results were:

- $\pm 2.77\%$ relative to F (± 0.101 for the original units (%));
- $\pm 2.59\%$ relative to CP ($\pm 0.085\%$ for the original units).

The SCC in milk was determined using the flow cytometry (FC) method on a fluoro-opto-electronic particle counter CombiFoss FT+ (Foss Analytical A/S, Hillerød, Denmark) or Somacount 300 (Bentley Instruments, Chaska, Minnesota, USA). These were regularly calibrated (CSN EN ISO 13366–1 and CSN EN ISO 13366–2) and checked for the reliability of the results. The combined expanded uncertainty of the measurement results was $\pm 9.3\%$ for $\text{SCC} < 900 \text{ } 10^3 \cdot \text{ml}^{-1}$.

MS Excel 2013 software (Microsoft Corporation, Redmond, Washington, USA) was subsequently used for statistical calculations. The basic statistical characteristics of the milk indicators of selected model dairy herds were determined.

2.3 Proposed SCC Data Processing Procedure and Selection Limits for Selecting Cows for Antibiotic Dry-Off

The basic analytical information was SCC in individual milk samples in the MR. As previously mentioned, SCC data transformation was used. The working tool of the transformation was the calculation of the so-called linear SCC score (SCS) according to the equation $\text{SCS} = \log_2(\text{SCC}(\text{ } 10^3 \cdot \text{ml}^{-1})/100) + 3$ (Shook, 1982; Reneau et al., 1983, 1988; Reneau, 1986), Table 1. There the critical value for suspicion of the occurrence of subclinical mastitis is $\text{SCS} > 4$ (Table 1), more exactly > 4.5 , which is equivalent to $\text{SCC} > 283 \text{ } 10^3 \cdot \text{ml}^{-1}$.

SCS was calculated for lactation SCC values from the MR of dairy cows. These SCS values in lactation dynamics were evaluated according to the procedure in Table 2. There the limit statistical criteria for assessing individual cases of dairy cows ending lactation were proposed by qualified estimation according to previous experience. After assessment, each case was assigned the symptom ATB and noATB according to variant I, Table 2. The frequencies of occurrence of these cases were assessed by relative statistics and compared with the literature and realistic assumptions.

Other conditions for evaluation according to Table 2 are:

- each evaluated dairy cow must have at least 5 SCC records in the MR during lactation before the dry-off

Table 1 Relative milk yield losses along SCC according to SCS and by lactation (according to Reneau et al., 1988)

Linear SCC	SCC ($10^3 \cdot \text{ml}^{-1}$)		Relative milk yield loss (%)	
	midpoint	range	first lactation	older cows
0	12.5	0–17	0	0
1	25	18–34	0	0
2	50	35–70	0	1
3	100	71–140	1.5	2.5
4	200	141–282	3.3	5
5	400	283–565	5.1	7.4
6	800	566–1,130	6.6	9.9
7	1,600	1,131–2,262	8.4	12.6
8	3,200	2,263–4,525	9.9	15
9	6,400	4,526 and up	11.7	17.5

date, for entry into the evaluation, indicating the order of lactation (1st and others);

- individual SCC values are transformed into SCS data with rounding to four decimal places;
- just before the end of the standardized (305-day) lactation (after 9 months), the arithmetic mean ($\bar{x}_9$), its standard deviation (sd) and the coefficient of variation (v_x in %) are calculated from the SCS data of the dairy cow;
- the dairy cow is marked in the MR data set as selected for the selected type of dry-off (noATB, noATB! and ATB) in relation to the order of lactation (first, others) according to the limit values of the SCS statistical parameters in the decision scheme in Table 2, in variants I and II, when it is likely that in practice the identification variant I will have a significantly higher frequency of occurrence;
- whenever an animal falls into one of the criteria (A, B or C) into a higher risk of mammary gland health (in the table down, in the type of treatment), it is preferentially marked for this type of treatment (assessment performed here). Another variant, changing (reducing) the frequency of occurrence of ATB indication, depending on the situation or location, may be a requirement to exceed two criteria for the ATB symptom.

The statistical procedure used was carried out according to the criteria in Table 2. However, in terms of the time frame it was not completely identical to the monthly output of the herd in the regular MR report. The given set contains the entire year of herd history it means some animals appear twice in two consecutive lactations in the period, some animals extend lactation and their entire lactations are used and not 9 months (which are defined due to the need to predict selection for the type of dry-off in the last, 10th month of the standard lactation), which will be taken into account systematically in reality.

There are therefore more minor differences as compared to the application of the procedure regularly after months of real MR in practice. However, because the calculation includes real MR data, the relative outputs of the selection pressure on the choice of noATB treatments at the dry-off may be similar and therefore comparable to the presented views on optimal functionality. The test is carried out on variant I (Table 2), which is sufficient to assess the validation result and possibly indicate a proposal for corrections of the selection criteria. In the case of variant II, it is just another, slightly modified variant of the same procedure.

3 Results and Discussion

3.1 Milk Indicator Results of Selected Cow Herds

According to the procedure above, 4 herds of Holstein (H 2 herds, 1 and 2) and Czech Fleckvieh (CF 2 herds, 3 and 4) dairy cows were evaluated for validation using a model (according to Table 2). The number of measurements after excluding dairy cows with less than 5 records in the MR was $n = 6,608, 3,996, 6,344$ and $4,187$, i.e. 918, 545, 941 and 606 dairy cows included in total. The average number (Tables from 3 to 6) of lactation order was 2.4, 2.3, 2.7 and 2.6 (median always 2). The average daily milk yield was 35.02 ± 10.09 kg (v_x 28.8%), 36.7 ± 10.03 kg (v_x 27.3%), 27.67 ± 7.78 kg (v_x 28.1%) and 32.6 ± 7.69 kg (v_x 23.6%). Other statistical characteristics of milk indicators were broadly representative for the conditions of the Czech Republic. Characteristics for SCC, as a key indicator of selection for possible non-antibiotic dry-off in dairy cows, were (Tables from 3 to 6):

- for SCC 238 ± 765 $10^3 \cdot \text{ml}^{-1}$ (v_x 321%), 171 ± 48 $10^3 \cdot \text{ml}^{-1}$ (v_x 579%), $339 \pm 1,103$ $10^3 \cdot \text{ml}^{-1}$ (v_x 325%) and 199 ± 703 $10^3 \cdot \text{ml}^{-1}$ (v_x 354%), $\bar{x}_9$ 76 $10^3 \cdot \text{ml}^{-1}$, 48 $10^3 \cdot \text{ml}^{-1}$, 113 $10^3 \cdot \text{ml}^{-1}$ and 51 $10^3 \cdot \text{ml}^{-1}$, m 66 $10^3 \cdot \text{ml}^{-1}$, 39 $10^3 \cdot \text{ml}^{-1}$, 97 $10^3 \cdot \text{ml}^{-1}$ and 40 $10^3 \cdot \text{ml}^{-1}$;

Table 2 Selection of dairy cows according to the dynamics of individual SCS values in MR for the type of lactation dry-off – decision-making scheme

Lactation	1.	1.	1.	1.	1.	1.	≥ 2.	≥ 2.	≥ 2.	≥ 2.	≥ 2.
Variant	I	I	I	II	II	II	I	I	II	II	II
Type/Crit.	A	B	C	A	B	C	A	B	C	A	B
noATB	≤ 2x	< 4.3	≤ 33 and < 4.2	≤ 1x	< 4.2	< 30 and < 4.2	≤ 3x	< 4.5	≤ 38 and < 4.4	≤ 2x	< 35 and < 4.4
noATBI	-	-	-	2-3x	4.2-4.5	30 - 35 and < 4.2	-	-	-	3-4x	35-40 and < 4.4
ATB	≥ 3x	≥ 4.3	> 33 and ≥ 4.2	≥ 4x	> 4.5	> 35 and ≥ 4.2	≥ 4x	≥ 4.5	> 38 and ≥ 4.4	≥ 5x	> 40 and ≥ 4.2

Practical local interpretation variants: I – ATB/noATB; II – noATB, noATB! and ATB; MR – milk recording

Limit criteria of statistical parameters SCS (Crit.). A – number of monthly values of SCS per lactation > 4.5; B – x_s SCS per lactation; C – v_x SCS per lactation in % and at the same time limit x_{0i} , the preference of any worse classification (higher SCS and its variability) applies as a determining rule for the resulting classification

type of dry-off treatment: noATB (non-antibiotic dry-off with teat disinfection); noATBI (non-antibiotic dry-off with teat disinfection and other selected prophylaxis as support, e.g. use of sealant preparation or dry cow vaccine administration; noATB + vaccine); ATB (antibiotic dry-off, usually also with teat disinfection); ATBI (antibiotic dry-off with teat disinfection and other selected prophylaxis as support, e.g. use of sealant preparation or dry cow vaccine administration; ATB + vaccine). The authors applied the following criteria for the screening of relevant studies: (1) the study had to be a randomised controlled trial; (2) the study had to be published in English; (3) the study had to be published in the last 10 years (2014–2024).

Table 3 Basic statistical characteristics of milk indicators of the annual classified data set of a herd 1 of Holstein dairy cows in MR (2023–2024), all lactations

Indicator/parameter	Milk yield	F	CP	L	SNF	SCC	log SCC	SCS	U	FFAs	CA	AC	LO
Unit	kg·day ⁻¹	%	%	%	%	10 ³ ·ml ⁻¹	–	class	mg·1000 ml ⁻¹	mmol·100 g ⁻¹	%	mmol·l ⁻¹	–
<i>n</i>	6,600	6,605	6,605	6,605	6,605	6,605	6,608	6,608	6,605	6,605	6,476	6,605	
<i>x_s</i>	35.02	4.25	3.49	4.9	9.11	238	1.8798	2.6235	25.06	0.94	0.15	0.07	2.4
<i>x_g</i>						76							
<i>sd</i>	10.09	0.86	0.44	0.19	0.43	765	0.5755	1.8752	6.25	0.53	0.04	0.06	1.48
<i>v_x</i>	28.8	20.1	12.7	3.9	4.7	321	30.6	71.5	24.9	56.5	23.4	78.6	61.5
<i>m</i>	35.4	4.21	3.46	4.93	9.11	66	1.8195	2.4005	24.9	0.85	0.15	0.06	2

n – number of cases; x_g – arithmetic mean; x_g – geometric mean; sd – standard deviation (for $n - 1$); v_x – coefficient of variation (%); m – median; F – fat content; CP – crude protein content; L – lactose monohydrate content; SNF – solids non fat content; SCC – somatic cell count; $\log SCC$ – logarithm of somatic cell count; SCS – linear score of somatic cell count; U – urea concentration; $FFAs$ – free fatty acid content of milk fat; CA – citric acid concentration; AC – acetone content; LO – lactation orderlin MR, indicators such as milk yield, fat and protein content and somatic cell count are regularly evaluated from a breeding point (genetical improvement) of view, and indicators such as lactose content, urea and acetone concentration are usually also taken into account in subsequent advisory service

Table 4 Basic statistical characteristics of milk indicators of the annual classified data set of a herd 2 of Holstein dairy cows in MR (2023–2024), all lactations

Indicator/parameter	Milk yield	F	CP	L	SNF	SCC	log SCC	SCS	U	FFAs	CA	AC	LO
Unit	kg·day ⁻¹	%	%	%	%	10 ³ ·ml ⁻¹	–	class	mg·100 ml ⁻¹	mmol·100 g ⁻¹	%	mmol·l ⁻¹	–
<i>n</i>	3,996	3,992	3,992	3,992	3,992	3,991	3,991	3,991	3,992	3,992	3,636	3,992	
<i>x</i> _s	36.7	4.37	3.58	4.9	9.19	171	1.6806	2.0026	27.97	1.13	0.15	0.05	2.3
<i>x</i> _g						48							
<i>sd</i>	10.03	0.93	0.49	0.16	0.48	579	0.576	1.83	7.74	0.62	0.04	0.06	1.42
<i>v</i> _x	27.3	21.4	13.6	3.3	5.2	339	34.3	91.4	27.7	54.8	24.3	126.0	61.1
<i>m</i>	36.7	4.3	3.51	4.91	9.16	39	1.5911	1.6415	27.8	1.08	0.15	0.05	2

abbreviations are explained under Table 3

Table 5 Basic statistical characteristics of milk indicators of the annual classified data set of a herd 3 of dairy cows of the Czech Fleckvieh breed in MR (2023–2024), all lactations

Indicator/parameter	Milk yield	F	CP	L	SNF	SCC	log SCC	SCS	U	FFAs	CA	AC	LO
Unit	kg·day ⁻¹	%	%	%	%	10 ³ ·ml ⁻¹	–	class	mg·100 ml ⁻¹	mmol·100 g ⁻¹	%	mmol·l ⁻¹	–
<i>n</i>	6,344	6,341	6,341	6,341	6,341	6,341	6,341	6,341	6,341	6,341	6,200	6,341	
<i>x</i> _s	27.67	4.01	3.65	4.89	9.28	339	2.0522	3.1817	29.1	0.65	0.14	0.09	2.7
<i>x</i> _g						113							
<i>sd</i>	7.78	0.81	0.43	0.24	0.42	1,103	0.57	1.88	6.88	0.49	0.04	0.09	1.65
<i>v</i> _x	28.1	20.3	11.7	4.9	4.6	325			23.6	76.5	26.6	96.7	61.7
<i>m</i>	27.6	3.94	3.64	4.93	9.28	97	1.9868	2.9561	28.8	0.62	0.14	0.08	2

abbreviations are explained under Table 3

Table 6 Basic statistical characteristics of milk indicators of the annual classified data set of a herd 4 of dairy cows of the Czech Fleckvieh breed in MR (2023–2024), all lactations

Indicator/Parameter	Milk yield	F	CP	L	SNF	SCC	log SCC	SCS	U	FFAs	CA	AC	LO
Unit	kg·day ⁻¹	%	%	%	%	10 ³ ·ml ⁻¹	–	class	mg·100 ml ⁻¹	mmol·100 g ⁻¹	%	mmol·l ⁻¹	–
<i>n</i>	4,187	4,185	4,185	4,185	4,185	4,185	4,185	4,185	4,185	4,185	3,660	4,185	
<i>x</i> _s	32.6	3.94	3.64	4.95	9.3	199	1.7053	2.078	27.28	0.75	0.14	0.09	2.6
<i>x</i> _g						51							
<i>sd</i>	7.69	0.6	0.39	0.16	0.38	703	0.589	1.883	4.58	0.6	0.03	0.07	1.73
<i>v</i> _x	23.6	15.2	10.8	3.1	4.1	354	34.5	90.6	16.8	80.1	22.8	77.8	66.2
<i>m</i>	32.0	3.9	3.64	4.95	9.3	40	1.6021	1.6781	27.1	0.7	0.13	0.08	2

abbreviations are explained under Table 3

- for log SCC 1.8798 ± 0.5755 , 1.6806 ± 0.576 , 2.0522 ± 0.57 and 1.7053 ± 0.589 ;
- for SCS 2.6235 ± 1.8752 and median 2.4005 , 2.0026 ± 1.83 and m 1.6415 , 3.1817 ± 1.88 and m 2.9561 and 2.078 ± 1.883 and m 1.6781 .

3.2 Frequencies of ATB/noATB Cases in Milk Recording Dairy Cow Herds

According to these results, in relation to the occurrence of milk secretion disorders (especially subclinical mastitis), the herds can be described as relatively very good to average (worst herd 3) with regard to the health status of the mammary gland. Therefore, these herds are suitable both for the application of practical selection for noATB treatment at dry-off at the end of lactation, and for the methodical implementation of statistical validation of the effectiveness of the proposed procedure. The absolute frequency of ATB/noATB cases by herds, breeds, lactations and criteria in Table 2 are summarized in Table 7, where it is also possible to confront differences between herds with respect to the stated health status (SCC, in Tables 3 to 6).

In total (Table 8, Figure 2), from the model herds (H and CF in MR), for the validation of the selection procedure for dairy cows for a certain type of lactation termination, 29.1 (H 1), 14.8 (H 2), 21.0 (CF 3) and 14.4 (CF 4) % of cows would be dried without ATB administration and 70.9 (H 1), 85.2 (H 2), 79.0 (CF 3) and 85.6 (CF 4) % with ATB. For a random selected sample of MR herds, a total of $19.8 \pm 6.9\%$ (v_x 34.8%) and $80.2 \pm 6.9\%$ (v_x 8.6%). This summarized and averaged relative proportion of $80.2 \pm 6.9\%$ (with ATB) may appear, from the perspective of the objective of the validation procedure, to be higher than would be necessary, as discussed further. This indicates the need for a more moderate

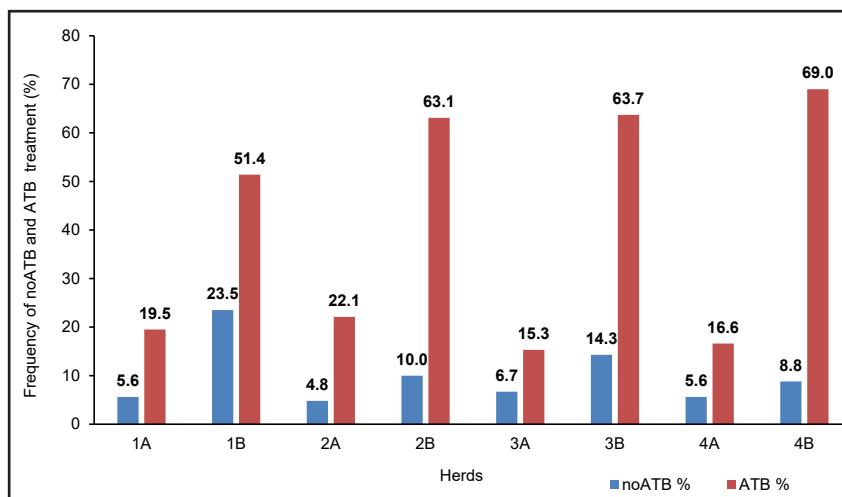


Figure 2 Relative (in %) assessment of case frequencies for noATB and ATB treatments (according to Table 8) at the end of lactation for 4 model herds of dairy cows of breeds H (2) and CF (2)
1A – H (1) on 1st lactation; 1B – H (1) on $\geq 2^{\text{nd}}$ lactation; 2A – H (2) on 1st lact.; 2B – H (2) on $\geq 2^{\text{nd}}$ lact.; 3A – CF (3) on 1st l.; 3B – CF (3) on $\geq 2^{\text{nd}}$ l.; 4A – CF (4) on 1st l.; 4B – CF (4) on $\geq 2^{\text{nd}}$ l.

correction of the selection criteria (Table 2) towards a higher proportion of noATB cases in the practice. A similar conclusion logically follows from an indirect type of confrontation of the average annual SCC values in milk from tanks in the Czech Republic with the results achieved here. The average of the averages for the last 10 years (2015–2024) is $230 \pm 6 \cdot 10^3 \cdot \text{ml}^{-1}$ (v_x 4.3%; Sládek, 2025). The variability of the average SCC values in these 4 selected herds from MR is for x_a $237 \pm 73 \cdot 10^3 \cdot \text{ml}^{-1}$, for x_g $72 \pm 30 \cdot 10^3 \cdot \text{ml}^{-1}$ and for m $61 \pm 27 \cdot 10^3 \cdot \text{ml}^{-1}$. The arithmetic means here show only a slight difference ($-7 \pm 10^3 \cdot \text{ml}^{-1}$). However, the proportion of noATB cases of $19.8 \pm 6.9\%$ (Table 8, Figure 2) is significantly below the rationally justifiable limit of approximately 50%.

3.3 Discussion about noATB/ATB Cases and Milk Losses Due to SCC with Relevant Sources

In developed dairy countries and in Finland in particular, a move away from the conventionally established practice of widespread dry-off in dairy cows under an ATB shield as part of mastitis prophylaxis was

initiated (about 15 years ago). The reason was the identified risk of bacterial resistance growth due to excessive application of ATB in dairy farming. The total proportion of cows in the 2nd and higher lactations treated with ATB at dry-off was (Niemi et al., 2022), in herds practicing selective treatment ($n = 172$) of dried cows with ATB (2015–2017), 25% (1,176/4,720). The aforementioned 25% indicates that 75% of cows in the 2nd and higher lactations were dried without ATB. This is therefore a relatively high figure that can ensure significant cost savings on ATB preparations. This ratio can also contribute to reducing the potential for ATB penetration into the environment. This may reduce the risk of subsequent development of ATB resistance in microbial mastitis pathogens. This can be generally described as a benefit. However, it is always necessary to be careful (Niemi et al., 2022) when performing the aforementioned selection so that the application of the procedure is not too harsh and thus to the detriment of the entire intended purpose. The aforementioned ratios should be assessed based on the incidence of subclinical mastitis (SM), as these

Table 7 Validation evaluation of frequency statistics (according to Table 2, variant I) of the occurrence of cases of interest (noATB and ATB) in model dairy herds

Case definition	Herd 1 H	Herd 2 H	Herd 3 CF	Herd 4 CF
NDC with < 5/≥ 5 records in MR	183/735	106/439	199/742	142/464
NDC on 1 st lactation	290	190	289	184
NDC on 1 st lactation with < 5/≥ 5 records in MR	106/184	72/118	126/163	81/103
NDC on 2 nd and higher lactation	628	355	652	422
NDC on 2 nd and higher lactation with < 5/≥ 5 records in MR	77/551	34/321	73/579	61/361
NDC on 1 st lactation with ≥ 5 records in MR, class A, noATB/ATB	168/16	112/6	143/20	102/1
NDC on 2 nd and higher lactation with ≥ 5 records in MR, class A, noATB/ATB	463/88	280/41	393/186	304/57
NDC on 1 st lactation with ≥ 5 records in MR, class B, noATB/ATB	174/10	113/5	145/18	103/0
NDC on 2 nd and higher lactation with ≥ 5 records in MR, class B, noATB/ATB	483/68	295/26	446/133	326/35
NDC on 1 st lactation with ≥ 5 records in MR, class C, noATB/ATB	42/142	22/96	51/112	26/77
NDC on 2 nd and higher lactation with ≥ 5 records in MR, class C, noATB/ATB	181/370	48/273	122/457	42/319

NDC – number of dairy cows; MR – milk recording database; H – Holstein; CF – Czech Fleckvieh

Table 8 Overall, absolute and relative, assessment of case frequencies for noATB and ATB treatments at the end of lactation for 4 model herds of dairy cows of breeds H (2) and CF (2)

Herd	Breed	Lactation order	Number of records per lactation during one year of MR ≥ 5	n = 100 %	noATB n	ATB n
1	H	1 st	184	735	41	143
1	H	≥ 2 nd	551	735	173	378
2	H	1 st	118	439	21	97
2	H	≥ 2 nd	321	439	44	277
3	CF	1 st	163	742	50	113
3	CF	≥ 2 nd	579	742	106	473
4	CF	1 st	103	464	26	77
4	CF	≥ 2 nd	361	464	41	320

usually exceed the incidence of clinical mastitis by a factor of 10. The ratio of SM occurrence in dairy herds, depending on the conditions, is a qualified estimate of 10 to 35%. This value approximately corresponds to the achieved ATB dry-off ratio in the aforementioned selecting herds in Finland. Underestimation may mean losses in milk and the health of the cows in the following lactation (Niemi et al., 2022). The aforementioned estimate is important for the initial setting of the selection pressure in the discussed procedure (Table 2). Appropriate selection pressure setting (criteria, Table 2) to obtain a ratio of approximately 50% of cows for ATB treatment could reliably cover cases of SM occurrence during lactation. This would bring both a significant reduction in ATB costs and a significant reduction in the risk of their possible penetration into the environment. Such a result would mean that almost all SM could be treated with ATB at dry-off and the remaining cases, where the occurrence of SM in lactation would be minimized, would undergo a dry-off without ATB, only with the application of teat disinfection and possibly teat sealants. This is the stated

goal of the procedure and the selection criteria (Table 2) will be gradually modified in practice to this effectivity.

However, in similar diagnostic statistics, a certain percentage of false positive (F+) and false negative (F-) cases will always remain in the expression of results (monthly MR report for farmers). Logically, the error rate cannot be 0%. This is an inherent property of such procedures. The occurrence of these F+ and F- cases means that some cases are “unnecessarily” administered with medication, while others are not treated “by mistake”. For the reasons stated, individual cases were also captured in the above model results in the overview (e.g. SCC fluctuated 8 times in lactation in the range of 20 to 40 so that in the 9th month the value was 270 10³·ml⁻¹), which meant a de facto F+ case. Such a specific case would not normally require ATB treatment at dry-off; however, in the evaluation, it bypassed the third criterion of result variability (Table 2) and was therefore incorrectly assigned to ATB treatment. In general, F- cases, which let the disease state go without the necessary treatment, are more risky than F+ cases, which mistakenly apply

treatment even in the case of a healthy mammary gland. Therefore, an F+ case is in no way the same severity as an F- (F+ < F-). In this regard, it is necessary to work with adjustments to the settings of the procedure's selection criteria (Table 2) so that there is practically always a higher percentage of F+ than F- cases, the occurrence of which should be minimized. In the case mentioned, it could be concluded that the solution would be (Table 2) to shift the condition in the procedure of $1 \times \text{ATB}$ from three applied criteria = total ATB to $2 \times \text{ATB}$ = total ATB, or to manipulate the individual criteria purposefully. Relevant corrections of the criteria will therefore be necessary during the practical start-up of the procedure in the MR.

Milk yield loss due to mastitis (mostly subclinical) increased with increasing number of test days with $\text{SCC} \geq 100 \cdot 10^3 \cdot \text{ml}^{-1}$ (Hadrach et al., 2018). Mastitis milk loss is by 33 to 45% lower in first lactation than in subsequent lactations (Hand et al., 2012). Cows with daily $\text{SCC} 200 \cdot 10^3 \cdot \text{ml}^{-1}$ had a 24-hour milk loss ranging from 0.35 to 1.09 kg and with $\text{SCC} 2,000 \cdot 10^3 \cdot \text{ml}^{-1}$ from 1.49 to 4.70 kg. Milk loss per lactation increased significantly, ranging from 165 to 919 kg, as the lactation mean SCC increased. In slight contrast, a reduction in exaggerated expectations regarding the effectiveness of eliminating mastitis-related milk yield losses has been newly reported (Chen et al., 2021). A suitably adjusted selection procedure for ATB dry cow treatment (how does this work test) can also contribute to reducing milk yield losses, in addition to reducing ATB consumption under current conditions in dairy farming.

Pokludová (2022), in the context of describing the ongoing rationalization and effective use of ATB, mentioned the decrease in the consumption of veterinary antimicrobics in the Czech Republic (CR) in the period 2010–2021 by 47%. Further, she confronts this fact to the EU requirement to maintain a decrease of 50% (as also this work assumes). She also comments, in the antimicrobial consumption data corrected for the relevant livestock populations, that the position of the CR in this consumption (50.02 mg/PCU) within the EU/EEA is above the EU median (47.6 mg/PCU) and below the EU average (84.4 mg/PCU). Pokludová (2022) then converted the result of the registration of the purchase of doses of DC IMM preparations (dry cow, lactation dry-off, intramammary with ATB, number of doses of DC IMM/4) in the CR to the number of treated dairy cows in the CR in 2021 with the result of 65.83%. Further, she also mentioned a decrease in the consumption of DC IMM (with ATB) in the period 2018–2022 in the CR by 25%. In the same period there was an increase in the consumption of intramammary plugs Seal IMM without ATB by 39% and also an increase in the consumption of antimastitis vaccines by 94%. This is evidenced by the gradual

reduction in the consumption of ATB in dairy farming through rational adaptation of technology and methods of care for the health of the mammary gland of dairy cows. This also means that there is still room for rationalization of ATB application in dairy farming, which is in accordance with the required concept of socially acceptable animal husbandry (Bennewitz et al., 2021).

Hasoňová et al. (2025) in a questionnaire survey with random selection ($n = 93$) estimated the proportion of dairy herds with widespread ATB dry-off in dairy cows for the CR at 29%. Pechová et al. (2024) similarly mention up to 58% (in 2023). This is roughly the segment where a benefit to the efficiency of the use of ATB in dairy farming can be objectively expected when introducing a procedure for evaluating dairy cows for ATB dry-off from routine data sets within the MR (as this paper, Tables 7 and 8, Figure 2). The value of 29% may then correspond to the estimate of approximately 66% (Pokludová, 2022) of treated cows. It could be logical when there are 29% of herds with widespread ATB dry-off and 71% of herds where this procedure is performed on approximately 25 to 75% of animals. Fleischer (2023) also mentions a summary of criteria for selecting dairy cows for ATB dry-off from various sources (different rearing systems, countries and approaches to the issue; according to the results of microbiology, mastitis tests, or SCC ; results from the entire lactation, the last three months, or the last month of lactation, etc.). Here some limits, e.g. for SCC above $50 \cdot 10^3 \cdot \text{ml}^{-1}$, could represent, under certain circumstances, the need for widespread use of ATB, when limits above $200 \cdot 10^3 \cdot \text{ml}^{-1}$ appear more realistic. Therefore, the need to validate these limits for selecting animals for antibiotic dry-off lactation according to specific rearing and health conditions, in which there is generally significant variability, is important.

4 Conclusions

A model validation of the proposed method of monthly selection of cows in MR for non-antibiotic lactation dry-off is described. The procedure is based on the basic health premise: "It is practically, biologically and ethically unacceptable to administer antibiotics to a healthy animal". The degree of bindingness of labeling dairy cows at the end of lactation as ATB/noATB is defined as a probabilistic recommendation. The specific decision on the selection of the lactation dry-off procedure is left to the zootechnician, or the decision of the veterinarian in specific, indicated cases.

The principles and discriminatory limits of the targeted selection procedure for non-antibiotic dry-off of dairy cows according to the dynamics of SCC during lactation

are presented and discussed. Selection of dairy cows for ATB/noATB dry-off of lactation can reduce:

- the use of ATB in mastitis prophylaxis and thus their penetration into the environment, i.e. also effectively reduce the risks of increasing the occurrence of residues of inhibitory substances in the dairy food chain;
- the risk of increasing bacterial resistance to ATB.

The procedure is innovative in that it represents another variant of the systematic use (expansion of the service portfolio of official dairy laboratories) of analytical results of regular milk recording (individual milk samples) for the creation and management of practical health measures to support the health of the milked herd and milk quality, and thus to support the efficiency of dairy cow rearing and the safety of the dairy food chain.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Name(s): role(s) Oto Hanuš – Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft. Josef Kučera – Funding acquisition, Data curation, Supervision, Validation. Hana Nejeschlebová – Investigation, Methodology, Validation, Writing – review and editing. David Lipovský – Data curation, Formal analysis, Investigation, Validation. Radoslava Jedelská – Data curation. Martina Tišnovská – Data curation, Formal analysis, Investigation. Irena Němečková – Supervision. Marcela Klimešová – Investigation, Validation.

AI and AI-Assisted Technologies use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

References

- Ali, A.K.A., & Shook, G.E. (1980). An optimum transformation for somatic cells concentration in milk. *Journal of Dairy Science*, 63(3), 487–490.
- Alenezi, M.S. et al. (2024). Antibiotic residues in milk and milk-based products served in Kuwait hospitals: Multi-hazard risk assessment. *Antibiotics*, 13, 1073. <https://doi.org/10.3390/antibiotics13111073>
- Arikan, M.S. et al. (2024). Determination of subclinical mastitis prevalence in dairy cows in Türkiye through meta-analysis and production loss calculation. *Pakistan Veterinary Journal*, 44(2), 391–399. <http://dx.doi.org/10.29261/pakvetj/2024.142>
- Atasever, S., & Erdem, H. (2009). Estimation of milk yield and financial losses related to somatic cell count in Holstein cows raised in Turkey. *Journal of Animal and Veterinary Advances*, 8(8), 1491–1494.
- Bennewitz, J. et al. (2021). Wege zu einer gesellschaftlich akzeptierten Tierzucht [Approaches to socially accepted livestock breeding]. *Züchtungskunde*, 93(3), 190–200. <https://www.zuechtungskunde.de/archiv/wege-zu-einer-gesellschaftlich-akzeptierten-tierzucht,QUIEPTY4OTlwMTkmTUIEPTY5MTU4.html>
- Boireau, C. et al. (2018). Antimicrobial resistance in bacteria isolated from mastitis in dairy cattle in France, 2006–2016. *Journal of Dairy Science*, 101(10), 9451–9462. <https://doi.org/10.3168/jds.2018-14835>
- Chen, H. et al. (2021). Estimating milk loss based on somatic cell count at the cow and herd level. *Journal of Dairy Science*, 104(7), 7919–7931.
- Fleischer, P. (2023). *Zdraví mléčné žlázy dojeného skotu – při zaprahování a následně* [Udder health in dairy cows – At dry-off and afterwards]. Česká technologická platforma pro zemědělství. <https://www.ctpz.cz/vyzkum/zdravi-mlecne-zlasy-dojeneho-skotu-a-pri-zaprahovani-a-nasledne-1457>
- Fleischer, P., Šlosárková, S., & Pechová, A. (2024). *Hodnocení chovů dojnic dle spotřeby antimikrobik a zdraví vemen prostřednictvím webové aplikace* [Evaluation of dairy farms by antimicrobial consumption and udder health using a web application] (Certified methodology No. 151/2024). Veterinary Research Institute. <https://www.vri.cz/wp-content/uploads/2025/01/CM-151-Slosarkova-Final.pdf>
- Hadrich, J.C. et al. (2018). Estimating milk yield and value losses from increased somatic cell count on US dairy farms. *Journal of Dairy Science*, 101(4), 3588–3596. <https://doi.org/10.3168/jds.2017-13840>
- Hand, K. et al. (2012). Milk production and somatic cell counts: A cow-level analysis. *Journal of Dairy Science*, 95(3), 1358–1362.
- Hanuš, O. et al. (2009). Research and development of a synthetic quality indicator for raw milk assessment. *Folia Veterinaria*, 53(2), 90–100. <https://www.uvlf.sk/document/fovia-veterinaria-volume-53-issue-2.pdf>
- Hasoňová, L. et al. (2025). Vyhodnocení možných faktorů ovlivňujících výskyt reziduí inhibičních látek v syrovém kravském mléce v České republice [Evaluation of possible factors affecting the presence of inhibitory residues in raw cow milk in the Czech Republic]. *Mlékařské listy – zpravodaj*, 36, 210(3), 12–16.
- Hisira, V. et al. (2024). Comparative analysis of methods for somatic cell counting in cow's milk and relationship between somatic cell count and occurrence of intramammary bacteria. *Veterinary Sciences*, 10, 5. <https://doi.org/10.3390/vetsci10070468>
- Kvapilík, J. et al. (2014). The economic importance of the losses of cow milk due to mastitis: A meta-analysis. *Bulgarian Journal of Agricultural Science*, 20(6), 1501–1515. <https://www.agrojournal.org/20/06-31.pdf>
- Kvapilík, J. et al. (2015). Mastitis of dairy cows and financial losses: An economic meta-analysis and model calculation. *Bulgarian Journal of Agricultural Science*, 21(5), 1092–1105. <https://www.agrojournal.org/21/05-28.pdf>

- Mašek, J. et al. (2022). Antimastitidní vakcinace jako varianta redukce použití antibiotik u dojnic – případová studie [Antimastitis vaccination as a variant of reduction to the use of antibiotics in dairy cows – A case study]. *Mlékařské listy – zpravodaj*, 33, 191(2), 8–13. http://www.mlekarskelisty.cz/upload/soubory/pdf/2022/veda_191_2.pdf
- Niemi, R.E. et al. (2022). Selective dry cow therapy effect on milk yield and somatic cell count: A retrospective cohort study. *Journal of Dairy Science*, 105(2), 1387–1401. <https://doi.org/10.3168/jds.2021-20918>
- Pitkälä, A. et al. (2004). Bovine mastitis in Finland 2001 – Prevalence, distribution of bacteria, and antimicrobial resistance. *Journal of Dairy Science*, 87(8), 2433–2441.
- Pechová, A. et al. (2024). *Selektivní zaprahování dojnic* [Selective dry cow therapy]. (Certified methodology no. 149/2024). Veterinary Research Institute. <https://www.vri.cz/wp-content/uploads/2025/01/CM-149-Slosarkova-Final.pdf>
- Pokludová, L. (2022, October 7). *Antibiotická politika, co je v platnosti a co nás čeká: Legislativa, systém sledování prodeje a používání ATM, odpovědné používání ATM* [Antibiotic policy – What is in force and what lies ahead? Legislation, monitoring systems for sales and use of antimicrobials, and responsible antimicrobial use]. ÚSKVBL. https://www.msd-farmarske-forum.cz/wp-content/uploads/sites/364/2022/12/01_Antibioticka_politika_co_je_v_platnosti_a_co_nas_ceká_Mgr_Lucie_Pokludova_PhD.pdf
- Pokludová, L. (2023, October 24). *Legislativa a používání veterinárních léčivých přípravků s přesahem do sektoru produkce mléka* [Legislation and use of veterinary medicinal products with implications for the milk production sector] Dny prvovýroby mléka 2023, ÚSKVBL. <https://cmsch.sprinx.com/getattachment/fb0136f1-028c-4a26-9539-1adbb71c5a60/Legislativa-a-pouzivani-veterinarnich-lecivych-pripravku-s-presahem-do-sektoru-produkce-mleka.pdf.aspx?lang=cs-CZ>
- Pyörälä, S. (2003). Indicators of inflammation in the diagnosis of mastitis. *Veterinary Research*, 34(5), 556–578. <https://doi.org/10.1051/vetres:2003026>
- Reneau, J. K., Appleman, R. D., Steuernagel, G. R., & Mudge, J. W. (1988). *Somatic cell count: An effective tool in controlling mastitis* (Publication No. AG-FO-0447). Agricultural Extension Service, University of Minnesota.
- Reneau, J.K. (1986). Effective use of dairy herd improvement somatic cell counts in mastitis control. *Journal of Dairy Science*, 69(6), 1708–1720.
- Roope, L.S.J. et al. (2019). Challenge of antimicrobial resistance: What economics can contribute. *Science*, 364, article eaau4679.
- Shook, G.E. (1982). Approaches to summarizing somatic cell count which improve interpretability. *National Mastitis Council, Louisville, Kentucky* (pp. 1–17).
- Singleton, D.A. et al. (2020). Factors associated with prescription of antimicrobial drugs for dogs and cats, United Kingdom, 2014–2016. *Emerging Infectious Diseases*, 26(8), 1778–1791. <https://doi.org/10.3201/eid2608.191786>
- Sládek, M. (2025). Výsledky kvality nakupovaného mléka v roce 2023 podle analýz bazénových vzorků [Quality results of purchased milk in 2024 according to bulk tank sample analyses]. (Report No. 21) Českomoravská společnost chovatelů, a.s. <https://cmsch.sprinx.com/cmsch/media/Rocenky/V%c3%bdsledky%20kvality%20nakupovan%c3%a9ho%20ml%c3%a9ka/Vysledky-kvality-nakupovaneho-mleka-v-roce-2023.pdf>
- Wilhelm, B. et al. (2009). Prevalence of zoonotic or potentially zoonotic bacteria, antimicrobial resistance, and somatic cell counts in organic dairy production: Current knowledge and research gaps. *Foodborne Pathogens and Disease*, 6(5), 1–15. <https://doi.org/10.1089/fpd.2008.0181>