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THE ECONOMIC IMPORTANCE OF THE LOSSES OF COW MILK DUE TO MASTITIS: A META-ANALYSIS

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Abstract

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Reducing the incidence of mastitis is measure aimed at increasing the quality of milk and dairy products. Effective economic argument for mastitis losses could contribute to promoting the prevention of this disease. According to literature data and model calculations the aim was to: - highlight the incidence of mastitis in cow herds; - analyze production losses caused by mastitis; - generalize the obtained knowledge. Relevant literature data (A) and two published data sets (B1 and B2) were statistically analyzed by method of meta-analysis. In addition to the milk losses also next economically important indicators were observed: - % of infectious animals; - somatic cell count (SCC) in milk; - the total count of microorganisms (TCM); - fat content (F); - protein content (P); - selected indicators of reproduction. Relationship between SCC and decrease in milk production showed correlation 0.775 ($P<0.01$). SCC increase by 100 $10^3.ml^{-1}$ results in a decrease in production (regression coefficient b=1.82) by 2.0% and vice versa. Relationship between SCC and lower milk production due to mastitis showed correlation 0.832($P<0.01$).With the increase in SCC by 100 $10^3.ml^{-1}$ the production is reduced by 51 kg per cow and lactation on average (b =0.511). Relations between SCC and other indicators were significant ($P<0.01$; B1 and B2).SCC increasing by 10 $10^3.ml^{-1-}$ resulted in reduction of F and P by 0.034 and 0.015% and TCM increase by 1.77 $10^3.ml^{-1}$ and decrease of F and P by 0.022 and 0.015% and TCM increase by 0.26 $10^3.ml^{-1}$.

Key words: cow, milk losses, percentage of infectious animals, somatic cell count, total count of microorganisms, fat and protein losses, losses of milk quality, dairy cow reproduction performance losses

Abbreviations: BCI – between calving interval; CMSCH – Czech Moravia Breeders Corporation; CORA – conception rate; CR – Czech Republic; EU – European Union; F – fat; P – protein; M – „mastitis“ milk; MR – milk recording; N – normal milk; NS – number of samples; SCC – somatic cell count; SP – service period; TCM – total count of microorganisms

Introduction

In accordance with the principles of the common agricultural policy of the European Union (EU) there is increasing attention paid to the food quality and safety. Also reducing the mastitis incidence is procedure which is included among the measures aimed at increasing the milk and milk product quality. Mastitis is, along with fertility disorders and lameness (Mitev et al., 2011; Varlyakov et al., 2012), the most common diseases of dairy production and a significant source of economic losses. According to Wendt et al. (1994) the mastitis is inflammation of the mammary gland in the complex of abilities to generate collect and eject milk. To evaluate the udder health state the German Veterinary Society (DVG 2002) developed definitions of normal milk secretion, latent udder infections and mastitis (nonspecific, subclinical, clinical and chronic). Subclinical mastitis is an udder in flammation without obvious symptoms with increased somatic cell count (SCC) and changed chemical milk composition and in two of the three analyzes can be detected pathogens. There are obvious signs of inflammation (higher temperature, pain, and swelling) at clinical mastitis and also milk shows macroscopic changes

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and cows often suffer from fever. Effective economic information and arguments about losses caused by mastitis could help to promote the prevention of this disease in dairy herds.

The goal of this paper was to: - highlight the incidence of mastitis in dairy cow herds; - analyze the production losses caused by mastitis; - obtain and generalize the relevant knowledge for possibility of practical use. This was based on literature data and model calculations and carried out by procedure of meta-analysis

Material and Methods

Methodical solutions of meta-analysis

This meta-analysis of production losses caused by inflammation of the udder is based on domestic and international scientific and professional publications (data A). In terms of classification of the used published results the occurrence (frequency) of mastitis in herds, the types and amounts of production losses and the factors that influence them are mainly reported. Data to estimate the mastitis incidence in the reviewed files were based either on the traditional classification of mastitis disease (Table 1; Siepelmeyer, 2011) or estimated by the milk SCC. Except nonspecific mastitis the higher SCC is characteristic and consensual for other types (Table 1). Therefore, SCC is one of more indicators of the raw milk quality in the breeding developed countries (Yilmaz and Koc, 2013). EU (Directiveno.92/46) and Czech Republic (CR; Edict No.203/2003Coll., CSN 570529) legislation demand among others less than 400 $10^3.ml^{-1}$SCC for processing of raw cow's milk. Milk SCC from cows with healthy udder is less than 100 $10^3.ml^{-1}$. Quarter sample SCC above 200 $10^3.ml^{-1}$ indicates the udder infection (National Mastitis Council, 2001). To estimate the relationship between indicators of the milk quality the results of analyzes of bulk samples in the CR (CMSCH laboratories, Inc.) for the period 2007 to 2013 (Kopunecz, 2014), and Bavaria (Milchprüfring Bayern e. V., 2014) for the year 2013 (data B1 and B2) were used. These results had been also practically used for payment purposes according to the milk quality in those regions.

Types and height of milk production losses due to mastitis

Mastitis has an adverse effect on production and economic results of dairy herds as well as any other disease. For the validation of data which (from literature sources) are entering into economic meta-analysis there is important to define the criteria for losses on livestock indicators such as milk yield and quality due to mastitis in dairy cows. The authors generally agree on the main types and causes of losses. The fewer consensuses exist about their observed or estimated amount. The following types of production losses are most common:

- the lower volume of sold milk due to lower milk yield during and after mastitis cure;
- the lower volume of sold milk due to its exclusion from delivery after antibiotic treatment;
- the higher culling of cows from rearing (higher herd change) due to mastitis;
- the higher veterinary performance (vet work) and drug consumption;
- the higher labour consumption of stable staff involved in the care of mastitis cows;
- the worsening of fertility indicators of dairy cows;
- the changes of milk chemical composition and its quality indicators;
- the others (analysis of samples, calf losses, diseases associated with mastitis, lower sales of animals, etc.).

In terms of economic viewpoint the most significant losses are caused by: - lower sales of milk (points 1 and 2); - higher culling of cows from herd (3); - the cost of treating cows (4). These losses (and higher labour consumption of herd staff) are usually included in the calculations of production and economic losses caused by mastitis. The economic importance of other types of losses is lower and difficult to determine. Therefore, their specification in the calculations is rather exceptional. These factors were therefore usually taken into account in the calculations and estimates. Literature data were systematically classified for the purposes of meta-analysis. This was made with milk indicators, which have a significant relationship to the economy of production. Re-

Table 1
Brief description of mastitis types – the underlying of meta-analysis method

Indicator	Mastitis			
	clinical	subclinical	nonspecific	latent
SCC ($10^3.ml^{-1}$)	> 100 – 150			< 100 – 150
pathogens	demonstrable		not detectable	demonstrable
udder	changed	unchanged	x	x
milk changes	clear	indistinct	x	x

Siepelmeyer (2011).

garding this facts, beside milk amount and its potential losses the following indicators of production, hygiene and quality were observed: - % of infectious animal (with mastitis pathogen finding); - the SCC; - the total count of microorganisms (TCM); - the fat content (F); - the protein content (P); - some indicators of reproduction performance (between calving interval (BCI), service period, insemination index).

Data statistic evaluation

The evaluated data files consisted of two (respectively three) above specified data sources (A and B (B1 and B2)). Data were processed by conventional statistical methods. There were designed basic parameters such as the mean values and characteristics of variability (Microsoft Excel). Relations between the included indicators were evaluated using linear and nonlinear regression. Significance of relationships was taken into account in end economic model calculations of production losses. The values of the milk volume were converted from pounds (lb) per kilogram (lb = 0.4536 kg) if necessary.

Results and Discussion

Mastitis in cows and SCC in milk

Requirements for SCC and other indicators to ensure the good health of udders of dairy cows (and milk quality) were established by number of authors. Siepelmeyer (2011) stated following characteristics inter alia: - SCC over 100 $10^3.ml^{-1}$ at less than 15% to 25% heifers and cows; - new infections during lactation and in the dry period under 50 and 15%; - the success of treatment during the dry period above 60%; - culling of cows out of herd due to mastitis below 4% for the year. According to the ZMP (2012) there are good indicators of the health status of the udder as follows: - SCC in bulk samples below 150 $10^3.ml^{-1}$; - the number of cows with SCC over 150 10^3ml^{-1} is less than 20%; - number of quarters with clinical inflammation is less than 20%; - number of cows culled from herd due to mastitis is below 7%. From the above mentioned requirements and according to data in Tables 2 – 5 this is evident that mainly SCC over 100 – 150 $10^3.ml^{-1}$, the number of new and repeated mastitis and growing proportion of dairy cows which were culled from herd due to mastitis indicate the need for the implementation of measures to improve the situation.

Due to the difficulty of resolution of healthy and mastitis cow udders, different farming conditions and other factors can not been stated exactly how many cows suffer from mastitis during year (Table 6). Clinical mastitis affects 17 – 48% of dairy cows per year. Annual average can be very roughly estimated at 30%. Published variability of subclinical mastitis is significantly greater than clinical. Subclinical mastitis is twenty to fifty times more common than clinical (Agribox, 2012; Wolter and Kloppert, 2002). Erskine (2011) reported their occurrence in 15 – 75% of cows (for disability 5 – 40% of udder quarters) and Nielsen (2009) in 33% of the cows. According to Fehlings (2013) and Siepelmeyer (2011) their proportion from all mastitis is higher than 90%. Schroeder (2012) respectively Kudi et al. (2009) estimated from 15 to 40 respectively 20 – 40 cases of subclinical mastitis per one clinical case.

Mastitis and milk production (sales) decrease

The relationship between the SCC in the bulk milk and a reduction in milk production per cow is shown in Table 7. Binding of SCC on the predicted prevalence of mastitis with relevant etiology by the occurrence of major pathogens in the bulk milk is given in Table 8. There are seen the values greater than 100 and 200 $CFU.ml^{-1}$ for occurrence of *Streptococcus agalactiae* and *Staphylococcus aureus* in bulk milk as suspicious for herd health. Both values correspond to the SCC of bulk milk 240 $10^3.ml^{-1}$ predict the prevalence of the mastitis 7.9 and 20.5%. In addition to the variability of mentioned indicators (Table 7) it shows that between SCC in the bulk milk and milk yield per cow per year there is a clear negative correlation. With the increase in SCC the milk production per cow and year is significantly reduced. It can be considered in the ideal SCC 100 – 150 $10^3.ml^{-1}$ with no or minimal decrease in milk production per cow. The SCC at around 400 – 800 $10^3.ml^{-1}$ reduces milk production per cow more than by 10%. Similar data indicated Stiles and Rodenburg (2012) (Table 9) and Blowey and Edmondson (1995). With the increase in SCC by 100 $10^3.ml^{-1}$ they showed a reduction in milk production by 2% (in SCC range from 100 to 1,000 $10^3.ml^{-1}$ decrease in milk production 0 – 18%), respectively by 2.5% (SCC range 200 – 500 $10^3.ml^{-1}$). If we divide the above data file (A) to intervals there is evident (Figure 1) that the milk loss is increased from 1% at SCC in bulk milk to 200 $10^3.ml^{-1}$ to 24% at over 1,000 $10^3.ml^{-1}$ of SCC. Relationship in 45 pairs of SCC (from 100 to 1,500 $10^3.ml^{-1}$) and milk production decrease indicates a significant correlation coefficient $r=0.775$ ($P<0.01$). The regression coefficient ($b=1.820$) indicates that an increase in SCC by 100 $10^3.ml^{-1}$ is in this range (from 100 to 1,500 $10^3.ml^{-1}$) resulted in a milk production decrease for the year by approximately 2.0% (Figure 2) and *vice versa*.

Milk production logically decreases with SCC increasing in milk from individual cows. There is shown in Table 10 a relatively high variability in the decrease in milk production with SCC increasing and significant difference in the milk production reduction between the first and second lactation. The difference in milk production per cow in SCC range from 100 to 1,000 $10^3.ml^{-1}$ can be estimated at 800 kg per lactation (Figure 3). Relationship between SCC and lower milk production due to mastitis expressed in 54 pairs the significant (P <0.01) correlation coefficient (r=0.832). From the regression coefficient (b =0.511) can be estimated that an increase in the SCC by 100 $10^3.ml^{-1}$ per cow and lactation reduced milk production by 51 kg of milk (Figure 4) on average. When milk yield per lactation is from 6,000 to 10,000 kg of milk is as a result of higher SCC by 100 $10^3.ml^{-1}$ a drop

Table 2
Requirements for milk yield and udder health of cows – the underlying of meta-analysis method

Indicator	Requirement
milk yield	- over 8,000 kg of milk per cow and year, lifetime milk yield 30,000 kg; - cow productive age over 3 years; - annual renewal of cow herd under 30%, of which less than 30% due to mastitis;
milk quality	- SCC in the sell milk below 180 $10^3.ml^{-1}$;
udder health state	- SCC at least 60% of cows under 100 and less than 8% of cows over 400 $10^3.ml^{-1}$; - less than 2% of clinically diseased cows udders; - less than 20% of recurring mastitis occurrence; - more than 90% of cows with bacteriologically negative milk.

Neike (2007).

Table 3
SCC and udder health of cows – the underlying of meta-analysis method

SCC in bulk milk sample ($10^3.ml^{-1}$)	Udder	Clinical mastitis occurrence in herd, %	Udder health state
< 125	healthy	< 24	good
125 – 250	suspect	24 – 60	improvement desirable
> 250	ill	> 60	improvement necessary

Wolter and Kloppert (2002).

Table 4
SCC in the bulk milk sample and udder health of cow herd – the underlying of meta-analysis method

SCC ($10^3.ml^{-1}$)	Udder health of cows	The proportion of infected udder quarters, %	Decrease in milk production, %
< 125	very good	x	0
125 – 250	good	6	0
250 – 375	satisfactory	16	6
375 – 500	suspect	32	18
500 – 750	disturbed	48	29
> 750	problematic	> 55	35

Winter (2008).

Table 5
Basic data on the characteristics of udder health of cow herd – the underlying of meta-analysis method

Indicator		Characteristic	Values, %	
			current	ideal
cows, SCC in individual milk >	100 $10^3.ml^{-1}$	subclinical mastitis occurrence	cca 50	under 25
	400 $10^3.ml^{-1}$	threat of exclusion of milk from delivery	cca 15	under 8
	1 000 $10^3.ml^{-1}$	cows with little chance of cure	cca 5	under 2
clinical cases per year		clinical mastitis occurrence	cca 50	under 12
1^{st} lac., SCC > 100 $10^3.ml^{-1}$ [1)]		mastitis occurrence in 1^{st} lactation	cca 40	under 5

Krömker (2010); 1) during first control day in milk recording, evaluation for one year.

Table 6
The reported incidence of clinical mastitis in dairy cows in different countries – data source for meta-analysis

State	Mastitis, %	Year	Author
Great Britain	16 – 20	1984	Bunch et al.
Canada	16.7 – 23.0	2008	Riekerink et al.
different states[1)]	17.0 – 39.9	1986 – 2002	cit. Maier
Canada	19.8	1998	Sargeant et al.
Lower Saxony	21.6	2001	Fleischer et al.
Netherlands	23.4	2008	Steeneveld et al.
Sweden	32	2009	Nielsen
USA	over 33	1998	Morin et al.
Germany	33.4[2)]	2005	Brinkmann et al.
Germany	35	2009	Lührmann
England and Wales	over 35	2007	Green et al.
Turkey	35.8	1993	Firat
Denmark	36 – 48	2001	Bartlett et al.
Germany	40	2010	Krömker
Great Britain	43.3	2004	Whitaker et al.
Saxony	45.2[2)]	2002 – 2003	Krömker et al.

1) Great Britain, USA, Finland, Australia and Germany; 2) enterprise with organic farming.

Table 7
SCC in bulk milk samples (.ml^{-1}) and lower milk production (%) – data source for meta-analysis

SCC (10^6)	Milk, %[1)]	SCC (10^3)	Milk, %[1)]	SCC (10^3)	Milk, %[1)]	SCC (10^3)	Milk, %[1)]	SCC (10^3)	Milk, %[1)]
0.1-0.2	0	< 125	0	150	0	< 100	< 2	200	0
0.2-0.5	4	125-250	0	200	0.75	100-200	2 - 4	500	6
0.5-1.0	9	250-375	6	300	2.25	200-500	4 - 8	1,000	18
1.0-5.0	14	375-500	18	350	3.00	500-750	8 - 10	1,500	29
5.0-10.0	30	500-750	29	400	3.75	> 750	> 10	x	
> 10.0	> 30	> 750	35	500	5.25	x			
Crist et al. (1997)		Winter (2008)		Tiergesundheit (2007)		Western Canadian (2013)		Current Concepts (1996)	

1) decrease of milk production (sale) as a result of mastitis.

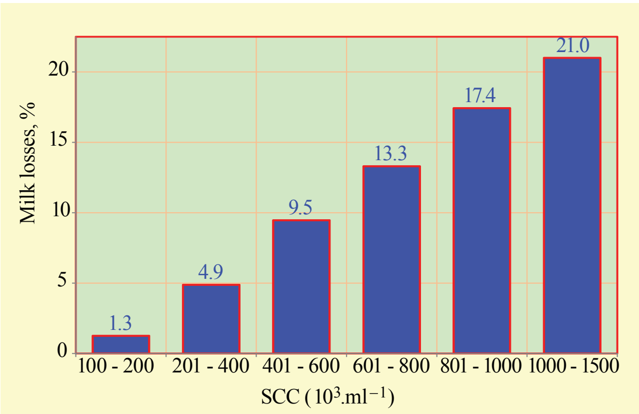
Table 8
The prediction table for estimation of prevalence of infectious mastitis of main etiology in dairy herds and bulk SCC by the occurrence of relevant pathogens in the bulk milk – the underlying of meta-analysis method

	Staphylococcus aureus		*Streptococcus agalactiae*	
Bulk milk CFU.ml^{-1}	prevalence estimation %	SCC estimation 10^3.ml^{-1}	prevalence estimation %	SCC estimation 10^3.ml^{-1}
0	0	150	0	150
10	1.7	160	1.0	160
50	7.3	180	4.6	200
100	12.6	210	7.9	240
200	20.5	240	13.4	290
300	26.7	290	17.8	340
500	36.2	360	24.6	400
700	43.5	410	30.0	490
1000	52.1	450	36.4	600
1500	62.9	600	44.6	800

Benda et al. (1997; modified); CFU = colony forming unit.

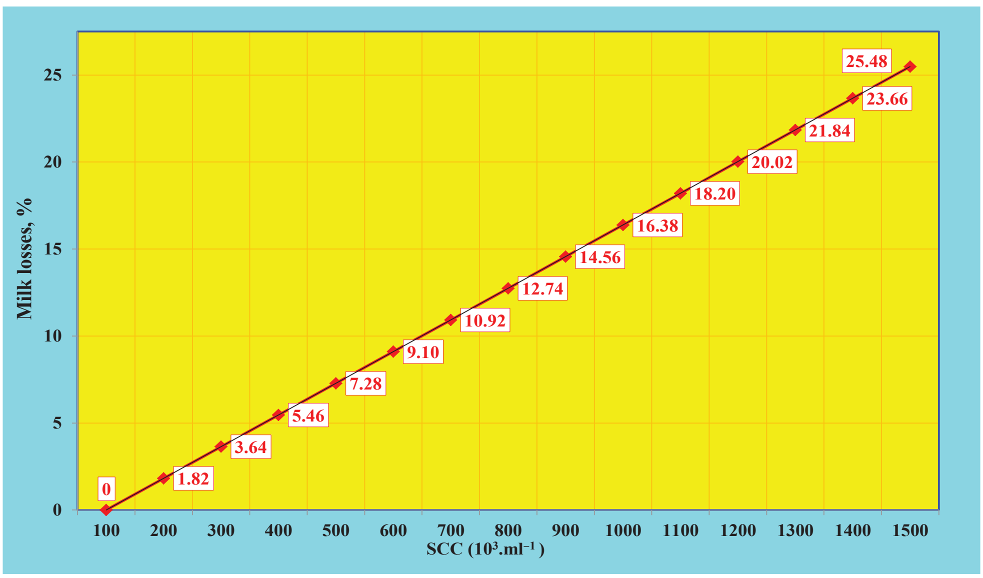
in milk production by 0.9 – 0.5%. When SCC increases from 100 to 400 $10^3.ml^{-1}$ is a drop in milk 2.7 and 1.5% respectively about 150 kg of milk. When the economic losses caused by mastitis are calculated is usually considered a reduction in milk production per occurrence of clinical or subclinical disease. As can be seen (Table 11) also this figure is characterized by considerable variability.

The second part of the "losses" of milk due to mastitis is the exclusion of supplies due to treatment with antibiotics. This period takes usually 7 – 8 days with 2 – 3 days for drug administration and with following 5 days for protection period after their application. The data (Table 11) show that the decrease in milk yield reached at a relatively wide range (200 – 528 kg) on average 342 kg, due to the exclusion of the milk from delivery (protection period) 222 kg (39 – 291 kg) and total then 639 kg (475 – 640 kg). Per one cow of herd (health and also mastitis) the nannual "loss" is equal to 85 kg (71 – 96 kg) of milk when cow mastitis incidence is 15% and 225kg (190 – 256 kg) in the presence of mastitis in 40% of cows. Lower milk sale is the largest economic loss caused by mastitis.



Calculation according to various authors (file A).

Fig. 1. The decrease in milk production per year and SCC in the bulk milk – results of meta-analysis



Calculation according to various authors (file A).

Fig. 2. SCC in the bulk milk and a drop in milk production (%) – results of meta-analysis

Table 9

SCC in the bulk milk and „losses" of milk per cow and year – data source for meta-analysis

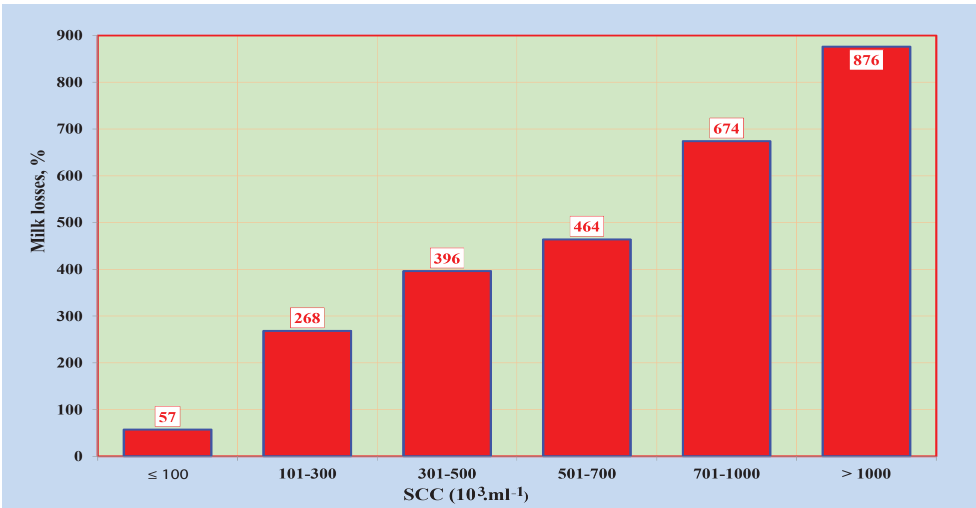
Milk losses	SCC in bulk milk ($10^3.ml^{-1}$)									
	100	200	300	400	500	600	700	800	900	1,000
%[1)]	3	6	7	8	9	10	10	11	11	12
kg[1)]	181	363	454	544	590	635	680	726	748	771
%[2)]	0	2	4	6	8	10	12	14	16	18

Somatic cell count (2012); Stiles and Rodenburg (2012).

Table 10
SCC in individual milk samples and lower milk production (kg/cow/year) – data source for meta-analysis

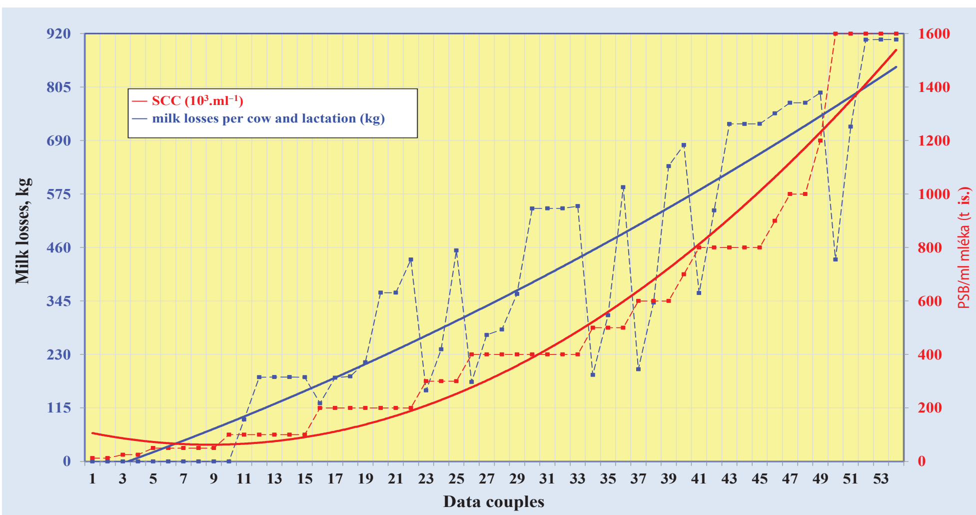
SCC (10^3.ml^{-1})	Milk, kg[1) 2)]		SCC (10^3.ml^{-1})	Milk, kg[1)]			SCC (10^3.ml^{-1})	Milk, kg[1)]
	1st lac.	2nd lac.		1st lac.	2nd lac.	mean lac.		
200	125	183	100	91	181	0	100	181
300	152	241	200	181	434	180	200	363
400	171	284	400	272	544	360	400	544
500	186	314	800	362	726	540	800	726
600	198	342	1 600	434	907	720	1 600	907
Exner (2009)			Raubertas and Shook (1982)			Stiles and Rodenburg (2012)	Schroeder (1997)	

1) decrease of milk production (sale) as a result of mastitis; 2) conversion of reported daily losses and a decline in milk production for 305 days of lactation (lac.).



Calculation according to various authors (file A).

Fig. 3. SCC in the individual milk samples and a drop in milk production (kg per year) – results of meta-analysis



Calculation according to various authors (file A).

Fig. 4. SCC and lower milk production per cow and lactation (kg) – results of meta-analysis

Table 11
The reduction in milk production due to clinical mastitis (kg) – data source for meta-analysis

Source, indicator			Lower production (sale) of milk, kg				
			per mastitis incidence due to			per cow of herd at mastitis, %	
			lower milk yield	protect. period	in total	15	40
Reiterer and Prünster (2007)[2)]			425	50	475	71	190
Heber (2013)			200	280	480	72	192
Schroeder (1997)[1)]			455	39	494	74	198
Tschischkale and Peters (2008)			250	280	530	80	212
Wulf (2009)			250	280	530	80	212
Harms (2009, 2013)			250	286	536	80	214
Mastitis (2008)			260	280	540	81	216
Schroeder (2012)			528	75	603	90	241
Lührmann (2009, cit. Tischer)			352	251	603	90	241
Dyson (2003)			330	291	621	93	248
Mahlkow-Nerge et al. (2007)			373	266	639	96	256
Tischer (2011)			400	240	640	96	256
Lührmann (2008)	lac. third	1st (70%)	423	296	719	108	288
		2nd (20%)	296	216	512	77	205
		3rd (10%)	169	152	321	48	128
		in total	373	266	639	96	256
mean			342	222	564	85	225
range (from - to)			200 - 528	39 - 291	475 - 640	71 - 96	190 - 256

cit. Tschopp (2010); 1) conversion of recognized loss in EUR at the selected price € 0.35 per kg of milk; protect. = protection.

Mastitis and cow culling (herd change)

Milk secretion disorders are usually the second or third health cause (after fertility disorders and cases of heavy birth) of cow culling. Higher culling (herd change) of cows from the herd is usually the second (after lower milk production) main cause of economic losses caused by mastitis. The proportion of culled cows from the herd because of a problem with the mammary gland of the total number of cull cows (100%) reported in Germany (or in its federative countries) Hachenberg (2013), LKV (2014), Gruisetal. (2004), Wolter et al. (1996), Harms (2009) and Wangleret al. (2009) between 14.3 and 30.3%, in Austria Fürst (2010) 12.2%, in England Esslemont and Kossaibati (1997) 10.1%, in France Seegersetal. (1998) 12.4%, in Sweden Nielsen (2009) 26.0%, in New Zealand Lacy-Hulbert et al. (2006) 10.4% and in the USA Jones (2009) 15.0%. In the CR this value fluctuated in the last three years in cows in the milk recording between 9.6 and 9.1% (MR, CMSCH2012 – 2014).

Culling of cows from the herd is usually an effective measure to eliminate chronic infectious cows. These can be a source of infection for their peers in the herd especially during milking. This is an effective method because there fall on 6 – 8% of dairy cows 40 – 50% of the total number of clinical mastitis (Mustafa, 2002) in the herds. When deciding between therapy and cow culling should be considered (Tischer, 2011) that:

- cow was treated more than twice in the course of lactation;
- there was found three times SCC over 700 $10^3.ml^{-1}$ in the individual daily milk;
- there is possible to identify nodules by udder palpation (*Staphylococcus aureus*);
- there are more than two udder quarters infected with *S. aureus*;
- the cow is on higher than third lactation.

In addition to these and other factors also revenue from sales of carcass cows and price (costs) of heifers which were included into herd require consideration and comparison.

Mastitis, veterinary actions and labour consumption

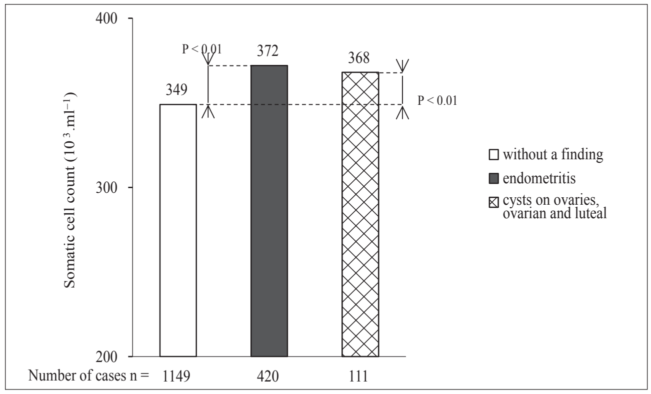
There are veterinary actions and drugs and the costs of prevention and treatment of mastitis as part of costs of dairy farming. Like all others, this item also features a large variability. It is caused by mastitis occurrence, implemented program of prevention and treatment, the type and price of drugs, vet labour price, etc. Portion of veterinary procedures and drugs on the economic loss caused by mastitis are usually presented between 4 and 40%.

Among the smaller (and usually reported) losses are included the costs for (more) work associated with the mastitis treatment (longer milking time, separation of milk which is excluded from the delivery, assistance at cow investigation and administration of the drugs, herd management, etc.). Labour consumption for these activities varies between 1and 4 hours (Lührmann, 2009). Average of ten data found in the literature corresponds approximately two hours on single occurrence of mastitis.

Mastitis and indicators of cow fertility

For a statistically significant effect of mastitis can be considered indicators of the deterioration of the cattle fertility. When mastitis has been detected there were investigated by various authors clearly lower pregnancy rates, longer service period (SP) and higher insemination index (Table 12). With the SCC increase in the bulk milk from 36 to > 284 10^3.ml^{-1} the SP and BCI extended (by 32 and 33 days), the insemination index increased (from 2.87 to 3.28) and milk yield per cow and year decreased (Table 13). Similarly, the individual SCCs were significantly higher when other reproductive complications in dairy cows were detected (Figure 5). Illness by mastitis two and one week prior to respective one week after insemination has resulted in a decrease of chance of cows become pregnant by 77 and 73% respectively 52% (Elite Magazin, 2009). Mastitis infection within 45 days after insemination increases the risk of early abortion compared with healthy cow almost three fold (Mastitis, 2012). At SCC 150, 311 and 1,800 10^3.ml^{-1} the number of seven- to eight-day live embryos was reduced from 18 to 6 and 4% (Roth et al., 2013).

Because fertility disorders of cows affected by mastitis are reflected in lower milk production or in higher herd change,



Hanus and Suchánek (1991).

Fig. 5. The relationship between the somatic cell count (SCC) in milk in the first half of lactation and reproductive complications of cows – the underlying of meta-analysis method

Table 12
Influence of mastitis on fertility indicators – data source for meta-analysis

Indicator	Mastitis no	Mastitis yes	Source	Indicator	Mastitis no	Mastitis yes	Source
CORA (%)	46[1)]	38[1)]	Kelton et al. (2001)	service period (days)	85	110	Shrick et al. (2001)
	63	48	Shrick et al. (2001)		88	107	Frago et al. (2004)
	63	48	Frago et al. (2004)		92	117[2)]	Klaas et al. (1999)
	68	77	Shrick et al. (2001)	insem. index	1.6	2.1	Kelton et al. (2001)
	73	86[2)]	Klaas et al. (1999)		1.6	2.1	Frago et al. (2004)
	42[3)]	35[3)]	Jahnke et al. (2002)		1.7	2.0	Klaas et al. (1999)

1) within 30 days after insemination; 2) subclinical and acute mastitis; 3) after first insemination (insem.); CORA = conception rate.

Table 13
SCC in the bulk milk sample, fertility indicators and milk yield of cows – data source for meta-analysis

SCC 10^3.ml^{-1}	Number of herds	SP days	BCI days	Insemination index	Milk per cow and year, kg
< 36	124	137	411	2.87	10 600
< 141	3 293	151	420	3.14	9 978
< 283	4 061	165	435	3.33	9 289
> 284	546	179	444	3.28	8 220

Smith (2003) cit. Zieger (2012); SP = service period; BCI = between calving interval.

the majority portion of economic losses is usually already included in these items. Therefore, the losses of lower fertility mostly are not reported.

Mastitis and fat and protein content and TCM in milk

Mostly three of indicators with possible relation to mastitis which are regularly investigated in raw milk can have direct impact on farmer milk price and on economic results of milk production: - the F content; - the P content; the TCM. The mastitis incidence (Table 14) has in all 11 cases resulted in a decrease in F content (approximately by 0.29%) and ambiguous decrease in P content (by 0.03%).

In Tables 15 and 16 there is considered the relationship between the SCC and other indicators of milk quality (F and P content, TCM) which were investigated for the purpose of milk payment by two sets (B1 and B2). The first includes the results obtained by CMSCH dairy laboratories for the period 2007 – 2013, the second than results found in 2013 in the laboratories in Bavaria for milk from Germany (from 7 Bavarian government districts and other Germany federal countries), Austria, Poland and the CR (33,350 suppliers). Milk analyzed in Bavaria (Table 15; B2) has lower SCC mean by 29%, higher F and P content by 0.19 and 0.07% and lower TCM by 58% than milk analyzed in the CR (B1). Nevertheless, mean and also maximal values of both sets of indicators meet the requirements of raw milk quality (standard CSN 57 0529) "with reserve". Relations between the SCC and other indicators were significant in both groups ($P < 0.01$; Table 16). According to the regression coefficients and course of dependencies between indicators (Figures 6, 7 and 8, Table 17) can be estimated that SCC increase by 10

Table 14
Mastitis and fat and protein in milk (approximate figures) – data source for meta-analysis

Source	Milk N[1] – M[2], %		Source	Milk N[1] – M[2], %	
	fat	protein		fat	protein
Thirapatsakun (2008)	-0.13 – -0.50	-0.27	Schroeder (2012)	-0.30	-0.05
Blowey and Edmondson (2010)	-0.17 – -0.50	decr.[3]	Şonea et al. (2009)	-0.40	+0.02
Schällibaum (2001)	-0.61	x	Foss (2002)	-0.30	-0.04
Jones and Bailey (2009)	-0.03	-0.04	Wolter et al. (1996)	decr.[3]	decr.[3]
Juozaitiene et al. (2004)	-0.33	+0.04	Wendt et al. (1994)	decr.[3]	decr.[3]
Kvapilík and Syrůček (2013)	-0.40	-0.12	mean (estim.)	-0.29	-0.03

1) N = normal milk; 2) M = „mastitis" milk; 3) considered when calculating the average with a decrease by 0.02% in fat content and 0.01% for protein content; decr. = decrease; estim. = estimation.

Table 15
SCC, TCM, fat and protein in the „monthly" bulk milk samples – results of meta-analysis

Indicator	B1 analyses (ČMSCH, a.s.)			B2 analyses (Milchprüfring)		
	mean	sd	from - to	mean	sd	from - to
SCC ($10^3.ml^{-1}$)	256	18.8	212 - 296	182	25.2	127 - 298
fat %	4.02	0.11	3.81 - 4.24	4.23	0.12	3.82 - 4.45
protein %	3.38	0.07	3.25 - 3.53	3.45	0.07	3.18 - 3.60
TCM ($10^3.ml^{-1}$)	40	6.5	28 - 55	17	1.6	11 - 25
NS[1]		84			156	

Kopunecz (2014); Milchprüfring Bayern e.V. (2014); 1) „monthly" averages the results of sample analyzes from individual suppliers; NS = number of samples; sd = standard deviation.

Table 16
Relations between the SCC, fat and protein content and TCM in bulk milk samples – results of meta-analysis

File	Data couples	Correlation coefficients (r) between SCC and		
		fat	protein	TCM
B1	84	-0.535**	-0.439**	+0.510**
B2	156	-0.508**	-0.469**	+0.630**

**$P < 0.01$.

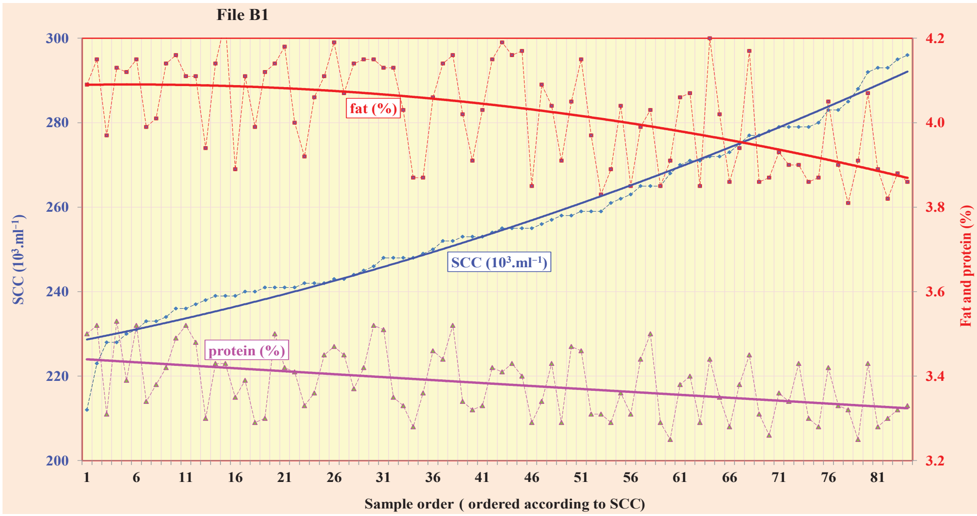


Fig. 6. SCC and fat and protein in the bulk milk (file B1) – results of meta-analysis Source: Kopunecz (2014).

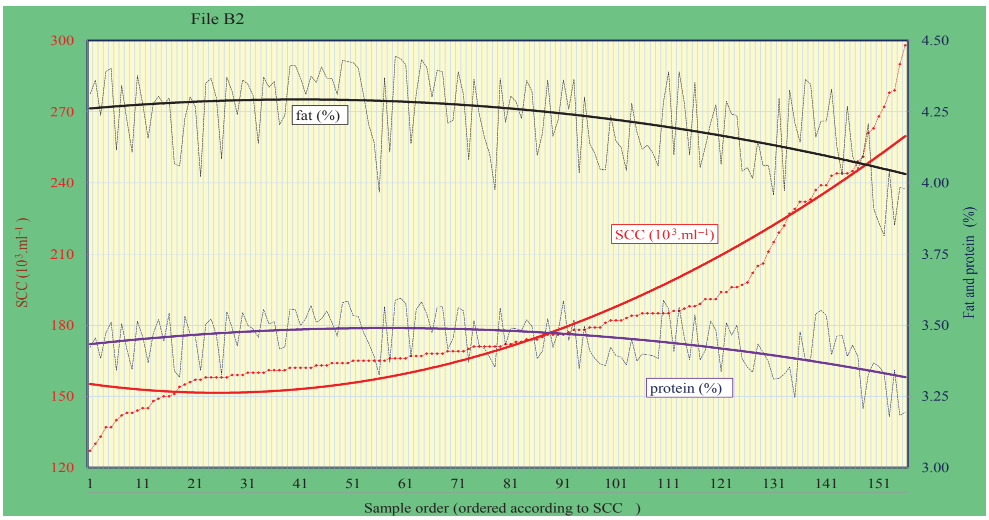


Fig. 7. SCC and fat and protein in the bulk milk (file B2) – results of meta-analysis Source: Milchprüfring (2014).

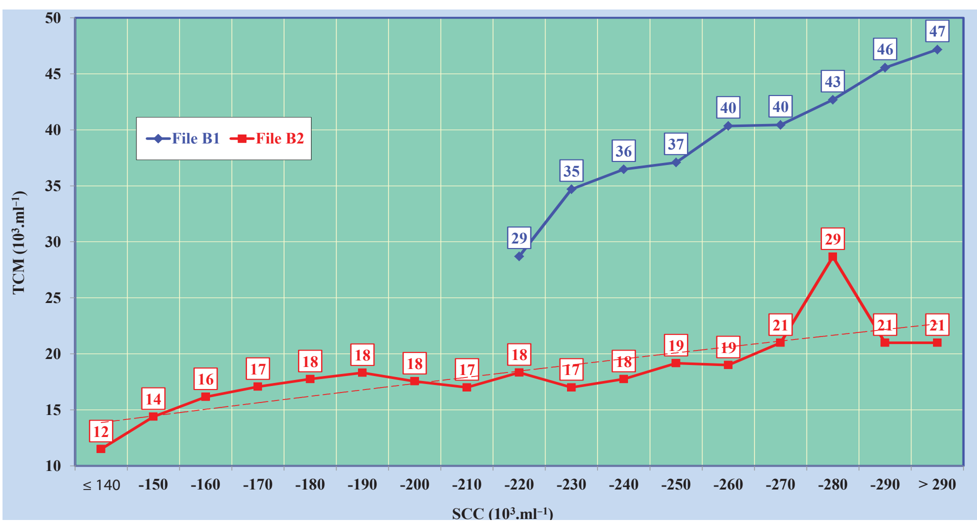


Fig. 8. SCC and TCM in the bulk milk (files B1 and B2) – results of meta-analysis Sources: Kopunecz (2014); Milchprüfring (2014).

10^3.ml^{-1} had at B1 file as result the reduction of F and P content by 0.034 and 0.015% and TCM increasing by 1.77 10^3.ml^{-1}. In the B2 file decreased F and P content by 0.022 and 0.015% and TCM increased by 0.26 10^3.ml^{-1}.

Conclusion

Direct and indirect production losses are the main basis for estimating the economic losses caused by mastitis. Their amount is usually impossible precisely detected for many reasons. Therefore, the mean and variability of production losses (Table 17) are estimated from the data and information contained in previous chapters. Due to a number of factors that influence production losses which are caused by inflammation of the udder (herd management, animal individuality, breed, order and stage of lactation, age of cow, nutrition and feeding, milking and housing, season, type of pathogens, etc.), it is necessary to use preferably the indicators identified in the evaluated herd or individual cows (cows culling, fertility, etc.) to estimate the concrete economic losses. When estimating the exact unobservable characteristics (for instance about decrease in milk yield) it must be take into account the conditions and results of a particular herd of cows.

The aim of paper was to assess production losses and estimate the economic losses caused by mastitis. Evaluation meta-analysis method validated using literature data. It can provide a higher explanatory power compared to the original data. However, on the other hand, literary sources include considerable variability in production conditions. This is balanced by carried out generalization seemingly. The mentioned fact is also necessary to take into account. Then such material can be used to increase efficiency of practical arguments for material support of prevention of production diseases in dairy cows.

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Table 17
The estimation of production losses caused by mastitis – results of meta-analysis

Indicator	Kind of loss		Loss		
			unit	mean	variability
milk (clinical mastitis)	lower milk yield		per mastitis occurrence (kg of milk)	350	200 – 500
	exclusion of milk from delivery[1)]			200	50 – 300
	milk loss in total			550	250 – 800
bulk milk (SCC)	lower milk yield at SCC (10^3.ml^{-1})	200 – 300	per occurrence (milk, %)	2	1 – 4
		301 – 400		4	3 – 6
		401 – 600		6	5 – 8
		601 – 1 000		9	6 – 18
individual cow milk (SCC)	lower milk yield at SCC (10^3.ml^{-1})	100 – 300	per mastitis occurrence (kg of milk)	150	0 – 300
		301 – 500		350	200 – 450
		501 – 700		450	300 – 600
		701 – 900		600	400 – 750
		over 900		800	500 – 1 000
culling and fertility (cow herd)	higher herd change		cows/100 cows	5	0 – 10
	longer SP and BCI		per occur. (days)	15	0 – 25
	higher insemination index		per occurrence and cow herd	0.3	0 – 0.5
	worse CORA (%)			10	2 – 15
bulk milk (components)	lower milk fat content		per 10 10^3.ml^{-1} SCC[2)] (%[3)], 10^3.ml^{-1} [4)])	0.025	0.005 – 0.04
	lower milk protein content			0.015	0 – 0.03
	higher TCM in milk			0.75	0.25 – 1.8
	lower milk fat content		per mastitis occurrence (%)	0.3	0.03 – 0.5
	lower milk protein content			0.03	+0.04 – 0.27
labour	higher consumption		per cow[5)] (hour)	2	1 – 4

Various authors, own calculations (estimation); 1) protection period for antibiotic treatment; 2) in SCC range from 100 to 300 10^3.ml^{-1}; 3) for fat and protein; 4) for TMC; 5) with mastitis; occur. = occurrence.

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