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SOMATIC CELLS IN BULK SAMPLES AND PURCHASE PRICES OF COW MILK

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Abstract

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There were calculated the somatic cell count (SCC) 209 (36–468) $10^3 ml^{-1}$, the total count of microorganisms (TCM) 25 $10^3 ml^{-1}$ (from 5 to 377), fat 3.84 % (from 3.23 to 4.46) and protein content 3.39 % (from 3.04 to 3.75) and milk freezing point (MFP) –0.525 °C (from –0.534 to –0.395) of the 522 monthly bulk milk samples from 11 experimental stables during the period from 2012 to 2015. Residues of inhibitory substances were not detected in any sample. Milk sale reached 7,999 liters (l) with fluctuating between 6,150 and 10,532 l per cow. This can be deduced from the regression coefficients that due to increase in the SCC by 100 $10^3 ml^{-1}$ the TCM increased by 2.9 to 4.2 $10^3 ml^{-1}$, the fat content decreased by 0.09 to 0.13 % and protein about 0.01 to 0.05 %. Influence of SCC, TCM and the fat and protein content calculated from monthly samples for individual stables can be estimated at –0.12 CZC, fluctuations between the stables at +0.46 to –0.84 CZC per l of milk. The increase in milk price by 0.17 CZC in the range of –0.92 to +0.92 CZC per l of milk corresponds to averages of indicators calculated from 522 samples.

Keywords: bulk raw cow milk, somatic cell count, fat, proteins, total count of microorganisms, milk freezing point, residues of inhibitory substances, milk secretion disorders – mastitis, quality and purchase price of milk

INTRODUCTION

The main sector of livestock production is rearing of dairy cows in most of EU countries and also in the Czech Republic (CR). The measures implemented to reduce inflammation in the mammary gland of cows can improve the less satisfactory long-term economic results in many herds in the CR milk production. Higher mastitis incidence usually has as an effect the increasing of costs on cow rearing and a decline in revenues from sale of inferior milk quality (Kossaibati and Esslemont, 1997; Rüsch, 2000; Walkenhorst, 2000; Krömker, 2007; Jones and Bailey, 2009; Nielsen, 2009; Hogeveen *et al.*, 2011; Lührmann, 2013; Kvapilík *et al.*, 2014). Inter alia, this follows also from the results of analyzes of bulk milk samples originating from farms included in the project "Research, new products and services to create a center of prevention detection and support of mastitis treatment" (QJ1210301). According to Zschöch (2016), there is not possible to replace successfully the analytic results of quarter milk samples by results of bulk samples in terms of checking of cow mammary gland health.

However, there is possible to assess the impact of the identified quality indicators of milk on its price by more reliable way. Therefore, the aim of this paper was to analyze the results of monthly obtained bulk samples and their using how to estimate their impact on the purchase milk price.

MATERIALS AND METHODS

Experimental dairy cow herds under antimastitis advisory service

There were implemented measures and reviewed the resources and procedures to reduce the mammary gland inflammation (mastitis) incidence in groups of dairy cows in selected farms (with some previous mastitis problems) under the solution of project QJ1210301 in duration of years 2013 and 2014. The results of this prevention and treatment part of the project will be released individually after their processing. This paper presents the results of analyzes of bulk milk samples that came from eleven experimental farms in period from 2012 to 2015. Here are calculated relations between milk indicators and derived their influences on the purchase milk price (MS Excel, Microsoft, Redmond, Washington, USA). The market production of milk per cow and year is taken from the enterprise records. Besides the means of basic data disagregated according to stables, years, calendar months and somatic cell counts (SCCs) also their main statistic characteristics are calculated. To estimate the influence of the contents of the main milk components on purchase milk price is used, beside identified relationships, the German Regulation on the quality and milk payment and amount of premiums and penalties for fat and protein unit paid in several dairies as well. To preserve the anonymity of the results the stables are randomly lettered A through L. The stated foreign prices are recalculated from European currency on Czech at the exchange rate of € 1 = 25 CZC (Czech crown).

Definition of counseling approaches

The character and list of targeted specific consulting activities in the field of prevention and control of mastitis in project dairy cow herds can be generally defined as follows. As known, mastitis as inflammation of the mammary gland as infectious (clinical, subclinical, latent) and nonspecific, both clinical and subclinical, both acute and chronic, are (as polyfactorial production diseases) associated with a number of pathological and technological influences. Therefore, these are related directly and primarily to a bacterial infection but also indirectly to a number of factors (often technological) including the occurrence of other production disorders such as metabolic imbalances, ketosis, acidosis, alkalosis, stress or limb disorders and which ultimately may weaken the body defense (immune) system and make the mammary gland open to infection pathogens. For those reasons the practical activities (correction measures) leading directly or also to mastitis control may be structured according to the nature of their focus. The following list of such prophylactic activities to mastitis limitations that have been used in the project experimental farms is structured just by their nature and is based on the fact that any mentioned measure was applied in herds at least once during experimental period. Another factor is that at least one correction measure has been carried out in every herd during the observation period (therapy, mammary gland care, a change in disinfection measures, the change in the rearing system and control of udder health – prevention of mastitis) in order to eliminate the inflammation of the mammary gland. Furthermore, some of measures were applied repeatedly in the herds – 1) measures to better milk hygiene: – the introduction of postdipping applicators; – change in type of predipping (foam preparate with lactic acid) and postdipping (plant extracts); – postdipping change to ApiBalm DIP Green – in total in 3 herds; – 2) measures to improved mastitis state of herd: – analysis of pathogens, their sensitivity to antibiotics and monitoring of somatic cell count (SCC) with follow-up measures as necessary; – bacteriological monitoring udder of heifers immediately after calving with measures by the results; – "Seal" application into the mammary gland during its drying; – an improvement in using of protocols with SCC records – in total 4 herds; – 3) measures to improved herd (animal) welfare – correction of cow drying schema; – change in the regime of the housing of high pregnant heifers and decrease in positive findings of pathogens; – ApiBalm cream application to support the treatment of acute cases of mastitis; – mechanical adjustment of feeding table – in total 4 herds; – 4) measures to better nutrition of dairy cows to lactation stabilization: – using a protocol about milk ketone bodies and operational applications of glucoplastic preparations (such as propylene glycol) in the cow diet – in total 1 herd.

Used analytical methods

The basic milk indicator is the SCC, the total count of microorganisms (TCM), fat and protein in milk and residues of inhibitory substances (RIL) are the other indicators. Milk samples were analyzed in accredited laboratories (LRM Brno-Tuřany and LRM Buštěhrad, ČMSCH a.s. Hradištko) on the fat (F, %), crude protein (P, %) and lactose monohydrate (L, %) content, the milk freezing point (MFP, °C) and SCC ($10^3 ml^{-1}$) using milk analyzers Bentley and Combi Foss 6000 and flow fluorooptoelectronic cytometers Somacount and Combi Foss 6000 (apparatus: Bentley Instruments, Chaska, USA; Foss Electric, Denmark). These instruments were regularly calibrated on so called reference methods: extraction by Roese-Gottlieb for F; distillation and titration according to the Kjeldahl method for P; enzymatic for L; cryoscopic for MFP (CryoStar Automatic, Funke–Gerber, Berlin, Germany); direct microscopy for SCC. Routine analytical instruments were continuously subjected to participate in regular analytical work proficiency testing with good results. Reference instruments and methods were regularly included in similar testing with successful results as well. Combined expanded uncertainties of measurement results were as follows: ±2.77 % relatively for F (±0.101 for the original unit (%)); ±2.59 % relatively for P (±0.085 % of original units); ±9.3 % for SCC (<900 $10^3 ml^{-1}$). TCM (in CFU $10^3 ml^{-1}$) was determined by flow cytometry using apparatus IBC and Bactocount (Bentley Instruments, Chaska, USA) after calibration to direct plate cultivation method results. RIL were determined by microbiological (*Geobacillus stearothermophilus*) inhibition test (growth at 65 °C) with pH indicator Eclipse 50 (WEU–INMUNOTEC, Spain) according to the relevant standard operating procedure.

RESULTS AND DISCUSSION

Brief characteristics of experimental farms

Eleven stables complied with requirements for their SCC evaluation in bulk milk (Tab. I). Market milk production of cows in these stables was on average of 7,999 liters (l) per year in the period from 2012 to 2015. This is by 642 l and 8.7 % more than the average sale per cow during the same period in the Czech Republic (CR, 7,357 l). The mean of four year milk production fluctuated between 6,150 and 10,523 l in these 11 herds. When variation from 50 to 580 cows the average reached 330 cows per herd. There were kept Holstein (H) cows in 8 stables,

I: *Selected technical and technological indicators of stables for dairy cows (n = 11)*

Stable	milk liters[1)]	cow/ stable	cow breed[2)]	area[3)]	number/day		milking parlor[5)]	pasture	
					feeding	milking		cows	heifers
A	8,419	450	H	N	5×	2×	R 2 × 10	no	yes
B	6,150	50	C	N	1×	2×	R 1 × 6	no	yes
C	9,919	580	H	N	2–5×	3×	R 2 × 12	no	no
D	8,325	210	H	N	2×	2×	R 2 × 12	no	no
E	8,460	350	H	P	1–2×	2×	R 2 × 10	no	no
F	6,931	190	H	P	2×	2×	SbS 2 × 6	yes	no
G	7,894	510	H	N	2×	2×	SbS 2 × 12	no	no
H	8,620	390	H	P	2–3×	3×	SbS 2 × 14	no	yes
I	6,374	130	C	P	2×	2×	R 2 × 5	no	no
J	6,373	220	C	P	2×	2×	R 2 × 6	no	no
K	10,523	540	H	N	4)	3×	R 2 × 12	no	yes

1) market output (sales) per cow per year, average for the period 2012–2015; 2) H = Holstein, C = Czech fleckvieh; 3) N = lowland (production), P = foothill and mountain; 4) as required; 5) R = fish bone parlor, SbS = parlor side-by-side.

II: *Selected milk recording and milk quality indicators identified in experimental herds, stables 414 (Ø 2012–2015)*

Indicator		herds	SCC $10^3 ml^{-1}$	TCM	milk	milk content %		MFP[1)]
		n		$10^3 ml^{-1}$	kg	fat	protein	–m°C
production area	lowland	6	219	21.6	8,538	3.86	3.41	526
	P + H[2)3)]	5	–22**	+7.3**	–1,186	–0.05**	–0.06**	–1
cow breed	H	8	212	24.8	8,637	3.78	3.34	526
	C[3)]	3	–11	+0.2	–2,338**	+0.21**	+0.18**	–2**
cow number in herd	to 200	3	165	25.5	6,485	3.99	3.45	524
	201–400[3)]	5	+55**	+1	+1,460	–0.17**	–0.09**	+2*
	over 400[3)]	3	+67**	–2.7	+2,704**	–0.25**	–0.08**	+2**
parlor type	fish bone	8	225	25	8,068	3.85	3.42	526
	side-by-side[3)]	3	–60**	–0.6	–253	–0.04	–0.13**	–1
milking number	2 × daily	8	204	22.9	7,366	3.88	3.4	525
	3 × daily[3)]	3	+20**	+7.5**	+2,321**	–0.16**	–0.06**	+1

*) the difference between the averages of relevant indicators significant on level $P < 0.05$; **) the difference between the averages of relevant indicators significant on level $P < 0.01$. 1) milk freezing point; 2) the foothill and mountain area; 3) ± to the average mentioned in the first line of relevant indicator.

Czech Fleckvieh (C) dairy cows in 3 stables. Six herds were in favorable (lowland) and five in less favorable (subalpine and alpine) area. Total mixed rations (TMR) were fed to dairy cows using feed wagons from one to five times a day. Dairy cows were milked in 8 fish bone and in 3 side-by-side milking parlors namely in 8 cases twice and in 3 cases three times a day.

Less favorable indicator is the only grazing cows and heifers in one and in four enterprises. Other technological indicators include in all cases free housing with different finish of surfaces to lie (straw, mattresses, separated manure and their combinations), ten stables had natural and only one forced ventilation, in all stables were drinking troughs. Ther was also high variability in the piling-up feed (in two stables without piling up to fifteen times daily as one stable) and the like. There was used milking management program with moist toilet of udder in all stables. Small differences between the stables existed in the cow mammary gland treatment before and after milking. The cows were milked usually into cans and exceptionally as a separate group in the parlor in the case of colostrum period and during mastitis. These and other data confirm that the project was solved in conventional stables with conventional workflows.

The means of SCCs and other indicators differed according to the production area, the herd size, milking techniques and the milking count (Tab. II). Significantly lower SCC ($P < 0.01$) was found in the foothills and mountains areas than in the lowlands at herd size up to 200 cows as compared to larger herds, for milking in parlor side-by-side than in a fishbone milking parlor and for twice before three times milking a day. Significant differences between the means show other indicators. It is obvious that neither significant differences between means are driven not only by the relevant factor and by technical and technological equipment barn respectively as it is given by the high frequency of factors which influence the results of cow rearing.

Content of components in bulk milk samples in individual stables

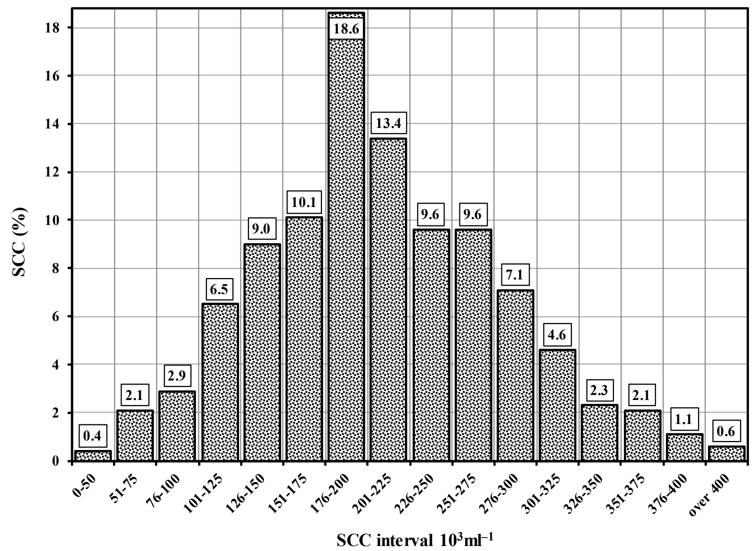
There are included the results of analyzes of 522 month bulk samples (for four years 10 stables × 48 samples + 1 stable × 42 samples) which were used by dairies to determine the purchase milk price. As the main indicator is considered SCC as additional TCM, RIL and content of protein and fat in milk. The means of these indicators in 11 stables for four years (2012–2015) are presented in the Tab. III. The calculated SCC mean from all 522 samples reached 209 (36–468) $10^3 ml^{-1}$ in this period, TCM 25 (5–377) $10^3 ml^{-1}$, milk fat 3.84 % (3.23–4.46) and protein content 3.39 % (3.04–3.75) and MFP –0.525 °C (–0.534 to –0.395). Sales of milk calculated as the mean of four assessed years reached 7,999 l with fluctuating between 6,150 and 10,532 l per cow. RIL in milk have not been detected in any sample and therefore it was not necessary excluded milk from deliveries nor enforce economic sanctions for this reason in any herd.

The TCM variability calculated from all 522 bulk samples is the largest of all evaluated parameters. With a mean of 24.9 $10^3 ml^{-1}$ and a standard deviation of 27.5 $10^3 ml^{-1}$ the identified TCM values fluctuate between 5 and 377 $10^3 ml^{-1}$. 476 (91.2 %) samples

III: *Mean indicators of bulk milk samples (n = 522[1)], 2012–2015)*

Stables, indicators	SCC $10^3 ml^{-1}$	milk[2)] l/cow	TCM $10^3 ml^{-1}$	fat %	protein %	MFP – m°C
A	250	8,419	25.9	3.63	3.39	526
B	121	6,150	20.3	4.19	3.57	522
C	284	9,919	37.1	3.71	3.39	524
D	267	8,325	17.9	4.04	3.43	528
E	187	8,460	30.7	3.71	3.24	525
F	145	6,931	19.0	3.84	3.27	525
G	180	7,894	14.6	3.88	3.35	527
H	168	8,620	41.7	3.70	3.25	524
I	230	6,374	37.3	3.93	3.50	524
J	252	6,373	17.6	3.83	3.48	526
K	212	10,523	13.8	3.73	3.36	529
mean[3)]	209	7,999	24.9	3.84	3.39	525
min.[3)]	36	6,150	5.0	3.23	3.04	395
max.[3)]	468	10,523	377.0	4.46	3.75	535
sd3)	72.2	1,375	27.5	0.23	0.15	6.5
v (%)	34.5	17.2	110.6	6.0	4.3	1.2

1) in the stable "H" 42 samples, in other stables 48 samples; 2) the mean market output (sales) of milk for four "year" milk sales; 3) from all 522 monthly milk samples; sd = standard deviation; v = variation coefficient.



1: *Frequency histogram of the SCC values in bulk milk samples (%)*

meets the Bavarian dairy Regulation requirement (Huber, 2016) for the class "S" (TCM ≤ 50 $10^3 ml^{-1}$) and for Class I and II (up to 100 and over 100 $10^3 ml^{-1}$) 34 and 12 samples (6.5 and 2.3 %) of the total number. Slightly lower than the found means in the milk of cows from experimental stables (24.9 $10^3 ml^{-1}$) are two months geometric means of TCM identified by Bavarian laboratories (MPR 2016) between 2012 and 2015 (in milk from Bavaria 16–17, Austria 12, Poland from 18 to 19 and CR 17–20 $10^3 ml^{-1}$).

The milk fat and protein content with means of 3.84 and 3.39 % show significantly less variability (sd = 0.23 and 0.15 %, v = 6.0 and 4.3 %) in comparison with the SCC and TCM.

Nevertheless, the difference between the lowest and the highest fat content is greater than 1 % (3.23–4.46) and in protein greater than 0.7 %

IV: *Selected indicators of 522 bulk samples (11 stables, Ø 2012 – 2015)*

SCC from – to	samples		SCC $10^3 ml^{-1}$	TCM $10^3 ml^{-1}$	milk content	
	n	%			fat	protein
0 – 50	2	0.4	26	7.5	4.32	3.60
51 – 75	11	2.1	66	15.2	4.21	3.61
76 – 100	15	2.8	88	28.4	4.07	3.49
101 – 125	34	6.5	114	22.6	3.93	3.37
126 – 150	47	9.0	137	25.3	3.89	3.33
151 – 175	53	10.2	164	19.3	3.81	3.34
176 – 200	97	18.6	187	25.9	3.81	3.36
201 – 225	70	13.4	214	20.9	3.81	3.38
226 – 250	50	9.6	238	26.1	3.86	3.44
251 – 275	50	9.6	263	29.7	3.82	3.40
276 – 300	37	7.1	288	27.1	3.79	3.43
301 – 325	24	4.6	312	22.0	3.74	3.39
326 – 350	12	2.3	333	44.0	3.77	3.36
351 – 375	11	2.1	366	32.1	3.74	3.33
376 – 400	6	1.1	388	20.0	3.85	3.41
over 400	3	0.6	443	34.7	3.49	3.30
mean[1)]	522	100	209	24.9	3.84	3.39

1) from all (522) monthly milk samples.

V: *The SCC in Bavarian, Austrian, Polish and Czech bulk milk samples*

Year	SCC mean (10^3ml^{-1})[1)] in samples coming from				
	Bavaria[2)]	**Austria[2)]**	**Poland[2)]**	**CR[2)]**	**file[3;4)]**
	three month geometric SCC mean (10^3ml^{-1})				
2012	168	141	256	259	204
2013	166	141	250	250	211
2014	165	146	248	234	198
2015	163	145	249	227	225
mean	165	143	251	243	209
	SCC over 400 10^3ml^{-1} (%)				
2012	4.9	4.1	18.0	15.3	0
2013	4.5	3.9	18.0	11.7	0
2014	4.3	4.1	17.4	9.4	0
2015	4.2	4.6	17.2	8.2	2.4
mean	4.5	4.2	17.7	11.2	0.6

Source: MPR Bayern (2016); Kopunecz (2016). 1) the number of samples analyzed in 2015 (thousands): Bavaria 1,621.2; Austria 34.2; Poland 37.3; Czech Republic (CR) 14.4; file 0.522; 2) the bulk samples analyzed in the Bavarian laboratories; 3) the bulk samples analyzed in the CR laboratories; 4) the "experimental" stables (n = 11).

VI: *Correlation and regression between SCC and selected milk indicators*

Coefficients	calculation from	pairs n	SCC 10^3ml^{-1} ×		
			TCM 10^3ml^{-1}	**protein %**	**fat %**
correlation	monthly samples	522	+0.076	–0.033	–0.282**
(r)	SCC intervals	16	+0.624**	–0.628**	–0.851**
regression	monthly samples	522	+2.88	–0.01	–0.09
(b)	SCC intervals	16	+4.21	–0.05	–0.13

VII: *Selected indicators of bulk milk samples[1)] by stables (11 stables, years 2012–2015)*

Year	indicator	10^3ml^{-1}		milk content %		MFP[2)]
samples[1)] (n)		**SCC**	**TCM**	**fat**	**protein**	**°C**
2012	mean	203	26.1	3.82	3.36	–0.525
(n = 132)	sd	57.2	36.1	0.22	0.14	11.7
	v	28.1	138.3	5.8	4.2	2.2
2013	mean	211	19.8	3.82	3.37	–0.525
(n = 132)	sd	73.0	23.4	0.22	0.16	2.5
	v	34.7	118.2	5.8	4.6	0.5
2014	mean	198	27.6	3.84	3.41	–0.525
(n = 132)	sd	65.6	27.1	0.24	0.14	3.3
	v	33.1	98.1	6.2	4.0	0.6
2015	mean	225	26.0	3.86	3.40	–0.527
(n = 126)	sd	87.5	19.7	0.24	0.14	2.9
	v	38.9	75.7	6.2	4.1	0.6
2015–2012	difference	+22*	+0.1	+0.04**	+0.04*	+2

1) the numbers of "monthly" samples; 2) the milk freezing point. * $P < 0.05$; ** $P < 0.01$.

(3.04–3.75). The fat content over 4.00 % and over 4.2 % was found in 149 (23 %) and in 67 (7 %) samples respectively. The milk protein content exceeded 3.4 % in 266 (45 %) samples. MFP varied (with the exception of extreme value of –0.395 °C) between –0.535 and –0.516 °C. It means that no sample had higher MFP value than required –0.515 °C.

It is apparent (according to Fig. 1 and Tab. IV) that most samples (18.6 %) is found in the SCC interval 176–200 $10^3 ml^{-1}$ and that only three samples (0.6 %) did not meet known EU and national requirement on SCC cut off limit for milk of standard quality (≤400 $10^3 ml^{-1}$). Of the 552 samples 466 (89 %) fulfilled Bavarian SCC limit (≤300 $10^3 ml^{-1}$) for the classification of this milk in Class "S" with a right to obtain the premium for kg of delivered milk. Despite of this favorable result and lower SCC than in CR and Poland milk indicated in Bavarian laboratories there is clear from Tab. V that SCC in experimental stables was higher than in Bavaria (about 45 $10^3 ml^{-1}$ and 75 %) and in Austria (about 100 $10^3 ml^{-1}$ and 70 %).

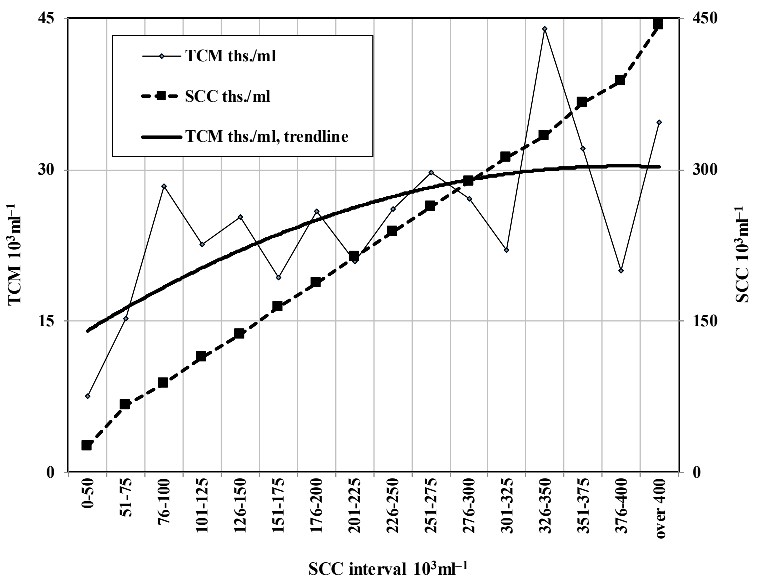
Correlation and regression relationships between milk indicators

Correlation and regression relationships between milk indicators are calculated from two data files. The first group consists of original 522 month samples, the second is created by month samples cumulated into 16 intervals according to SCC. In Tab. VI there is evident that in the calculation of 522 month samples is significant ($P < 0.01$) only correlation between SCC and milk fat ($r = -0.282$). However, according to the calculation of the accumulated data into 16 intervals, there are at the same level ($P < 0.01$) significant relationships between SCC and TCM ($r = +0.624$), SCC and protein ($r = -0.628$) and the SCC and milk fat content ($r = -0.851$). From the relevant regression coefficients can be deduced that the SCC increase by 100 $10^3 ml^{-1}$ in the calculation of monthly samples (522) is connected with TCM increasing by 2.9 $10^3 ml^{-1}$ (Fig. 2) and protein and fat content decreasing by 0.01 and 0.09 % (Fig. 3). In the case of interval calculation there is evident the TCM increasing by 4.2 $10^3 ml^{-1}$ and the protein and fat content decreasing by 0.05 and 0.13 %.

Kvapilík (2014) reported the results of 11 authors who investigated fat and protein content in milk of healthy cows and cows suffering from mastitis. Those mentioned lower fat content on average about 0.29 % (about –0.03 to –0.61) and ambiguous decrease of the protein content by 0.03 % (+0.04 to 0.12) in mastitis milk in all cases. Based on other literature data was estimated TCM increase by 7.5 $10^3 ml^{-1}$ (+2.5 to +18.0) and milk fat and protein content decreasing by 0.25 % (–0.05 to –0.4) and by 0.15 % (0 to –0.3) with SCC increase by 100 $10^3 ml^{-1}$.

Evaluated milk indicators in years 2012 and 2015 and in year duration

The means of evaluated indicators for all included herds and years are given in Tab. VII. Along variability common for the indicators with biological character the between years differences between SCC, TCM and also fat and protein are small. Therefore, one can not determine the impact of any antimastitis measures to improve the health status of mammary gland of cows. In the four years under review SCC means varied between 198 and 225 $10^3 ml^{-1}$, TCM between 19.8 and 27.6 $10^3 ml^{-1}$, fat content between 3.82 and 3.86 %, milk protein between 3.36 and 3.41 % and MFP between –0.527 and –0.525 °C. Between the last (2015) and the first year of evaluation (2012) was significant ($P < 0.01$) only the difference between milk fat means (+0.04 %) and at the limit of significance ($P < 0.05$)



2: *SCC and TCM in the bulk milk*

VIII: *Development of bulk milk sample indicators[1] between 2012 and 2015 (11 stables)*

Stable	SCC $10^3 ml^{-1}$		TCM $10^3 ml^{-1}$		fat %		protein %	
	2012	2015[2]	2012	2015[2]	2012	2015[2]	2012	2015[2]
A	199	+127	23.0	+1.5	3.68	–0.1	3.37	+0.02
B	193	–99	32.3	–15.4	4.22	–0.13	3.55	–0.03
C	286	+31	30.3	+8.9	3.71	–0.04	3.33	+0.07
D	256	+29	9.3	+14.0	3.85	+0.28	3.41	+0.02
E	188	–10	25.6	–4.9	3.67	+0.11	3.24	0
F	139	+15	17.3	+5.0	3.77	+0.26	3.21	+0.14
G	208	–50	17.4	–1.8	3.76	+0.2	3.35	+0.01
H	126	+146	48.3	+20.4	3.72	–0.09	3.28	–0.05
I	190	+63	56.5	–16.6	3.98	–0.04	3.44	+0.09
J	226	+46	17.6	–1.8	3.87	–0.04	3.48	0
K	230	–43	9.7	+11.3	3.83	–0.09	3.28	+0.16
in total	203	+22	26.1	–0.1	3.82	+0.04	3.36	+0.04

1) in total 522 (monthly) samples; 2) difference (±) to 2012.

IX: *SCC in bulk milk samples*

Year	number of samples	samples with SCC ($10^3 ml^{-1}$)							
		to 100		101–300		301–400		over 400	
		n	%	n	%	n	%	n	%
2012	132	0	0	126	95.5	6	4.5	0	0
2013	132	13	9.9	108	81.8	11	8.3	0	0
2014	132	8	6.1	117	88.6	7	5.3	0	0
2015	126	9	7.1	87	69.1	27	21.4	3	2.4
in total	522	30	5.7	438	83.9	51	9.8	3	0.6

X: *Bulk milk sample[1] indicators during the year (11 stables, Ø from 2012 to 2015)*

Stables / indicators	SCC	TCM	milk content (%)		MFP[2]
	$10^3 ml^{-1}$	$10^3 ml^{-1}$	fat	protein	(°C)
January	196	30.9	3.93	3.44	–0.526
February	191	24.0	3.94	3.45	–0.526
March	193	22.4	3.89	3.41	–0.527
April	183	24.5	3.84	3.37	–0.526
May	203	28.8	3.77	3.33	–0.523
Juni	225	19.8	3.73	3.29	–0.526
July	235	29.5	3.70	3.29	–0.525
August	240	21.7	3.68	3.27	–0.525
September	236	27.4	3.78	3.34	–0.525
October	212	22.7	3.89	3.44	–0.526
November	203	24.1	3.95	3.49	–0.527
December	196	22.7	3.99	3.50	–0.526

1) in total 522 (monthly) samples; 2) the milk freezing point.

the differences between SCC (+22 10^3ml^{-1}) and the milk protein content (+0.04 %).

Of the 11 enterprises between 2012 and 2015 the means of SCC, TCM, milk fat and protein content were increased in 7, 6, 4 and 7 herds and the means of the same indicators decreased in 4, 5, 7 and 2 farms (Tab. VIII). Investigated SCCs in the years 2012 to 2015 show a slight increase in the proportion of samples with SCC to 100 and marked increase in the proportion of samples with SCC from 300 to 400 10^3ml^{-1} of milk (Tab. IX). However, in another evaluation (Kvapilík *et al.*, 2016) of individual samples in milk recording from the same period and the same experimental herds there was identified marked SCC decrease (by 10 %) due to applied advisory service measures. This disproportion can be explained by the fact that in individual tests (Kvapilík *et al.*, 2016) there are included mostly all animals in herd while there is often organized routine operational milk selection of mastitis suspected cows from dairy plant delivery before examination of bulk milk samples just by the SCC results.

Milk quality indicators in each month of the year are given in Tab. X and Fig. 4 and 5. SCC development (the lowest in February–April, the highest in July–September), TCM and the milk fat and protein content (highest in winter and lowest in summer) is consistent with the literature data (Milchprüfring Bayern 2016; Info LKV 2016; Kopunecz, 2016) in most cases. The relationship between the SCC and TCM is almost zero (r = –0.002) and among the SCC and the milk fat and protein content are the relationships significant ($P < 0.01$, r = –0.773 and –0.701) despite of small number of pairs (n = 12).

XI: *The estimation of changes in milk production by SCC in bulk milk samples*

Indicator	SCC 10^3ml^{-1}	decrease %	
		mean	range
milk production per cow	to 200	0	0
	201 – 300	2	1–4
	301 – 400	4	3–6
	401 – 600	6	5–8
	601 – 1 000	9	6–18

Source: estimation according to Kvapilík *et al.* (2014) and by different authors.

XII: *Premiums and penalties for fat and protein unit in milk (CZC/unit)*

Dairy plant	± CZC per protein (P) unit				± CZC per fat (F) unit				ratio
	2014	2015	2016	Ø	2014	2015	2016	Ø	P/F[1)]
FrieslandCampina	1.62	1.26	1.15	1.35	0.81	0.63	0.57	0.67	1 : 0.5
Arla	1.47	1.21	1.14	1.28	1.12	0.81	0.71	0.88	1 : 0.7
Hochwald	1.25	1.25	1.25	1.25	0.63	0.63	0.63	0.63	1 : 0.5
DMK[2)]	1.25	1.25	1.25	1.25	0.63	0.63	0.63	0.63	1 : 0.5
MW Oberfranken	1.03	1.03	1.03	1.03	0.68	0.68	0.68	0.68	1 : 0.7
Austria[3)]	0.95	0.95	0.95	0.95	0.77	0.77	0.77	0.95	1 : 1.0
mean	1.26	1.16	1.13	1.18	0.77	0.69	0.66	0.71	1 : 0.6

Source: Current to Milk trade Milchmarkt, (2016); Milchgeld – Anlageblatt (2014, 2015, 2016). 1) the ratio between protein and fat, the calculation of means from mentioned years. 2) Deutsches Milchkontor; 3) data valid for dairies in Lower Austria.

XIII: *Premiums and discounts for milk quality to estimate its purchase price*

Indicator	unit	premium/penalty (CZC[1)]/kg of milk)	
		mean	range
TCM	≤50 10^3ml^{-1}	+0.20	+0.13 to +0.25
SCC	≤300 10^3ml^{-1}		
TCM	>100 10^3ml^{-1}	–0.60	–0.50 to –0.70
SCC	>400 10^3ml^{-1}	–0.35	–0.25 to –0.45
milk protein[2)]	unit	±1.10	±0.90 to ±1.30
milk fat[2)]		±0.65	±0.60 to ±0.70

Source: MilchGüV; Milchgeld – Anlageblatt (2016).
1) 1 € = 27.00 CZC; 2) standard values for protein and fat 3.4% and 4.0%.

XIV: *The estimation of production changes and purchase milk prices[1] (2012 – 2015)*

Stables	milk[2] %	CZC per liter (l) of milk						
		milk[3]	SCC + + TCM[4]	SCC	TCM	protein	fat	total
A	–2.0	–0.16	+0.15	–0.01	–0.01	–0.10	–0.24	–0.37
B	–0.3	–0.02	+0.18	0	–0.01	+0.19	+0.12	+0.46
C	–2.0	–0.16	+0.13	–0.01	–0.04	–0.01	–0.18	–0.27
D	–2.1	–0.17	+0.13	0	0	+0.03	+0.02	+0.01
E	–0.5	–0.04	+0.17	0	–0.04	–0.18	–0.19	–0.28
F	–0.1	–0.01	+0.20	0	0	–0.14	–0.10	–0.05
G	–0.6	–0.05	+0.20	0	0	–0.06	–0.08	+0.01
H	–0.5	–0.04	+0.01	0	–0.04	–0.39	–0.38	–0.84
I	–1.4	–0.11	+0.16	0	–0.01	+0.11	–0.04	+0.11
J	–1.8	–0.14	+0.16	0	0	+0.09	–0.11	0
K	–1.0	–0.08	+0.19	0	0	–0.04	–0.17	–0.10
Ø	–1.2	–0.10	+0.16	–0.002	–0.01	+0.10	+0.02	+0.17
min.	–6.0	–0.48	0	–0.35	–0.60	–0.30	–0.39	–0.92
max.	0	0	+0.20	0	0	+0.50	+0.40	+0.92

1) values from the results of the monthly analyzed bulk milk samples (42 samples G stable, other stables 48 monthly samples); 2) the estimation of reduction in sales of milk per cow by the SCC (Tab. XI); 3) an estimation of the reduction in milk prices from lower sales per cow (9,000 liters per cow and year, the price of CZC 8.00 per liter); 4) according to the maximum values for both indicators (Tab. XII).

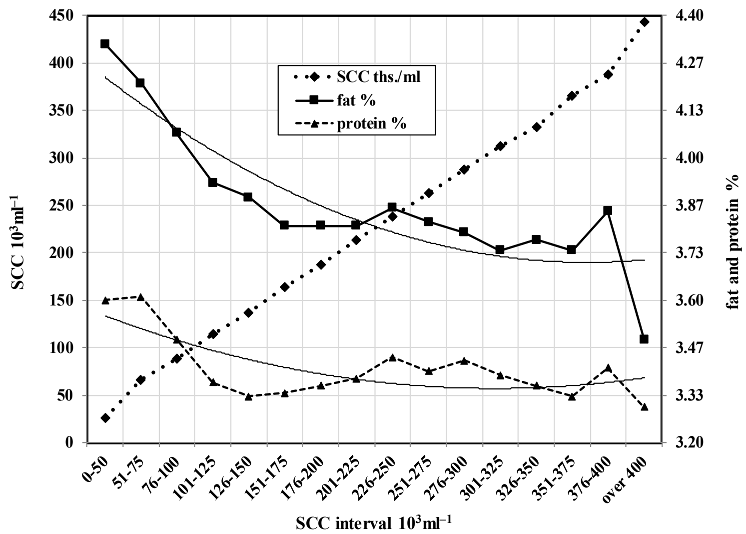
XV: *An example of the impact of fat and protein content on milk price in the German dairies*

Indicator		dairy plant							
		HW		Oberfranken		Schwälbchen		Arla	
		A[1]	B[1]	A[1]	B[1]	A[1]	B[1]	A[1]	B[1]
milk kg/cowu/day		30	30	30	30	30	30	30	30
milk fat content %		3.80	4.15	3.80	4.15	3.80	4.15	3.80	4.15
milk protein content %		3.10	3.25	3.10	3.25	3.10	3.25	3.10	3.25
price per	**fat**	0.68	0.68	0.73	0.73	0.65	0.65	0.71	0.71
unit CZC	**protein**	1.35	1.35	1.11	1.11	1.30	1.30	1.19	1.19
CZC[3]/kg	**basic milk price[2]**	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.94
	fat correction	–0.14	0.10	–0.15	0.11	–0.13	0.10	–0.14	0.11
	protein correction	–0.41	–0.20	–0.33	–0.17	–0.39	–0.19	–0.36	–0.18
	basic price + correction[4]	5.40	5.84	5.46	5.88	5.42	5.84	5.44	5.87
	VAT (10.7%)	0.58	0.62	0.58	0.63	0.58	0.63	0.58	0.63
	milk price + DPH	5.98	6.46	6.05	6.51	6.00	6.47	6.02	6.50
milk CZC/cow/day[4]		162	175	164	176	163	175	163	176

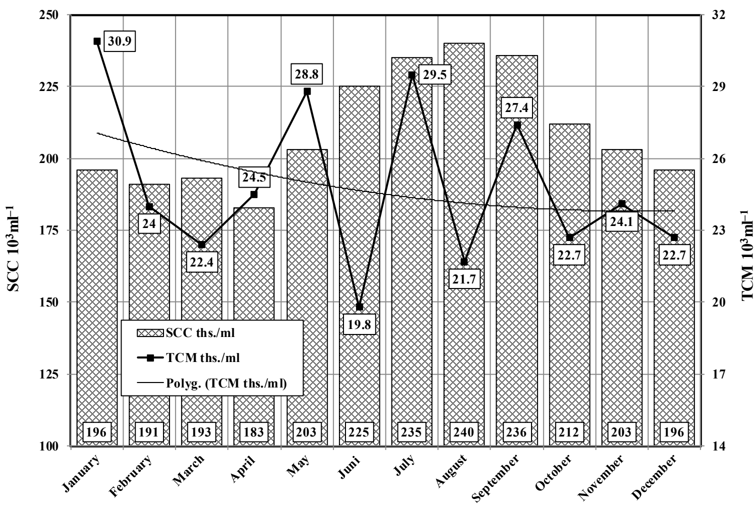
Source: Fetrow (2016). 1) A = initial indicators; B = modified indicators; 2) the basic price of milk at 4.00% of fat content and 3.40% of protein content; 3) 1 € = 27.00 CZC; 4) without VAT (the value added tax).

Evaluated indicators and milk prices

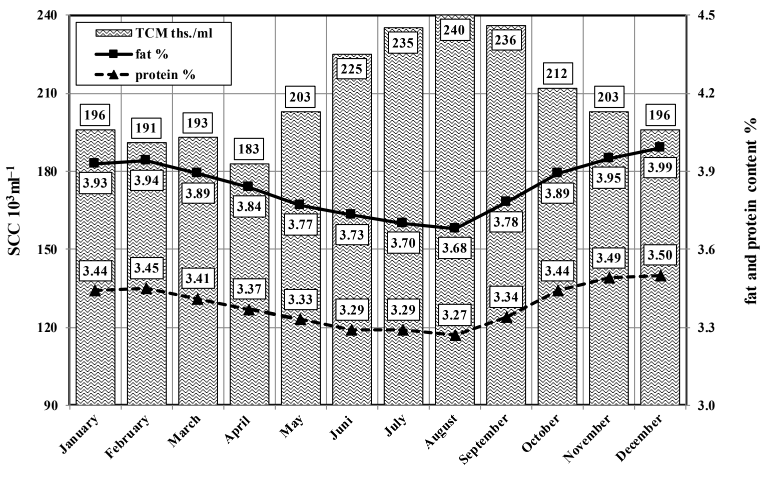
There is not included the lactose content of milk components into estimation of an impact on the purchase milk price. The reason is its here unproven relationship between lactose and SCC (r = –0.008) although in other papers was regularly demonstrated (e.g. –0.36 and –0.33, P < 0.001; Hanuš *et al.*, 2010) and the fact that in most of dairies lactose is not taken into account in milk price. However, it is part of purchase price in the company FrieslandCampina since January 1st 2014. The standard lactose content was stated at 4.51 % and price per unit to CZC 0.18 (the ratio of protein : fat : lactose is 10 : 5 : 1 and in CZC 1.78 : 0.89 : 0.18 respectively). When estimating the price there is not calculated also with RIL in milk because in no sample were detected. With the SCC change also milk production of dairy cows varies among others (Kossaibati and Esslemont, 1997; Rüsch, 2000; Walkenhorst, 2000; Krömker, 2007;



3: *SCC and the fat and protein content in the bulk milk*



4: *Months of the year, SCC and TCM (522 samples, 2012 – 2015)*



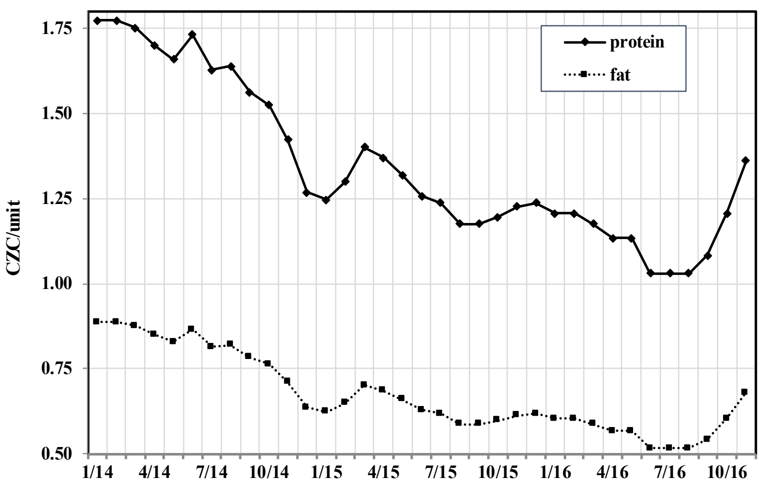
5: *Months of the year, fat and protein content in milk (522 samples, 2012 – 2015)*

Jones and Bailey, 2009; Nielsen, 2009; Hogeveen *et al.*, 2011; Lührmann, 2013; Kvapilík *et al.*, 2014). To estimate changes in milk production the data from Tab. XI are used. Most of dairies paid bonuses for SCC and TCM below the adjusted limit. For value higher than adjusted maximum the different levels of penalties from the milk price are set. The fat and protein content higher or lower than the standard values of these components is taken into account differently by dairies. Bonuses and penalties for unit of protein and fat in the German and Austrian dairies for the years 2014–2016 are listed in Tab. XII. Fat and protein unit price is changed more times yearly in some cases (eg. in FrieslandCampina, Fig. 6) but in the others is the same award several years (Hochwald, DMK etc.). Valuation methods for protein and fat components for Czech dairies are not published. Information from 2014 obtained as a personal communication values the protein and fat unit to 0.90 and 0.65 CZC (ratio 1: 0.72).

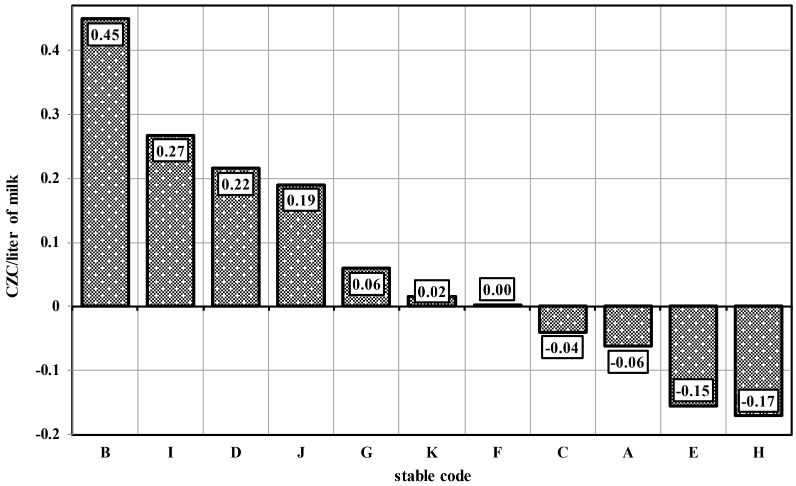
There is utilized the relationship between SCC and milk production per cow (of the Tab. XI), estimation of premiums and penalties for SCC and TCM in milk and prices for protein and fat units (1.10 and 0.65 CZC) then from Tab. XIII in a model calculation of milk prices (Tab. XIV). Milk composition and properties (SCC, TCM and the fat and protein content mean) influenced the level of purchase milk prices in the range of +0.45 to −0.17 CZC per liter of milk (Fig. 7) in experimental stables for the years 2012 to 2015. The sum of these two items (CZC 0.62) points to the reserves that exist there to improve the milk quality at the evaluated experimental file. Between 2012 and 2015 when there is presupposition the validity of the considered indicators, the height of milk componnents should show by increase of price by 0.24 and 0.31 CZC in stables A and H and decrease by 0.27 to 0.32 in the stables I and F (Fig. 8).

The impact estimation of SCC, TCM and protein and fat content found in 522 monthly bulk samples in eleven stables for the period 2012–2015 is presented in Tab. XIV. The effect of average indicators should be reflected in the 11 stables by price change from +0.46 CZC/l of milk in the stable B to −0.84 in the H stable. Under these conditions the average for all stables would reached 0.12 CZC per liter of milk. The increase in milk price by CZC 0.17 (from −0.92 to +0.92) is equal to average which was calculated from all 522 samples. At presupposition of the validity of considered indicators the biggest influence on the increase in purchase prices of milk would have bonuses for the milk quality. Under simultaneous achieving of stated maximal SCC and TCM (average CZC +0.16) and for protein content (+0.10 CZC) by the largest price penalty would be affected impact of higher SCC on cow milk production.

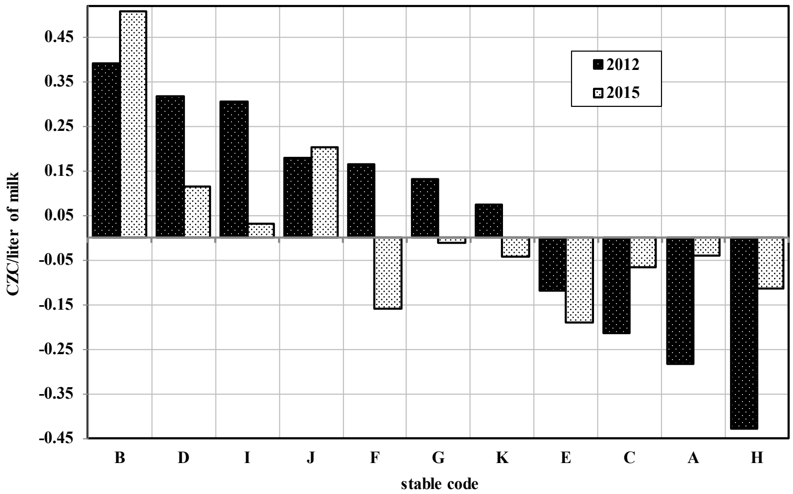
Effect of fat and protein content of milk prices in four German dairies is presented in Tab. V. The price per fat unit fluctuated between 0.65 and 0.73 CZC and per protein unit between 1.11 and 1.35 CZC for fat content between 3.80 and 4.15 % and protein between 3.10 and 3.25 %. Because the basic price of milk (as in the model calculation in Tab. XIV) is set at 4 % of fat and 3.4 % of protein the milk price is affected by penalty due to correction on protein content. Penalties for fat content were changed to bonuses due to fat content increase over 4 % after „change“ of indicators.



6: *Unit prices for protein and fat (CZC) in the dairy FC*



7: *Effect of components on the purchase milk price (CZC/liter, Ø years 2012 – 2015)*



8: *Effect of components on the purchase milk price (CZC/liter, 2012 and 2015)*

CONCLUSION

Influence of SCC, TCM and the fat and protein content calculated from monthly samples for individual stables can be estimated at −0.12 CZC, fluctuations between the stables at +0.46 to −0.84 CZC per l of milk. The increase in milk price by 0.17 CZC in the range of −0.92 to +0.92 CZC per l of milk corresponds to averages of indicators calculated from 522 samples. In the framework of identified results and solution of relationship between the bulk sample composition and milk price was showed among others that the SCC, TCP, RIS, protein and fat content, respectively lactose content and MFP can be used to estimate their impact on the purchase milk price. The sum of the individual effects is then "common denominator" as one number respectively expressing the approximate aggregate effect of all indicators on the purchase price of milk.

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REFERENCES

FETROW, J. 2016. *Innovationsteam Milch Hessen*. [Excel table]. Landesvereinigung Milch Hessen. Available at: www.milchhessen.de/mediaarchiv/grab_pic.php?id=34635 [Accessed: 2016, December 20].

GERMANY. 1980. *Milch-Güteverordnung vom 9. Juli 1980 (BGBl. I S. 878, 1081), die zuletzt durch Artikel 1 der Verordnung vom 17. Dezember 2010 (BGBl. I S. 2132) geändert worden ist*. Available at: https://www.gesetze-im-internet.de/bundesrecht/milchg_v/gesamt.pdf [Accessed: 2016, December 20].

HANUŠ, O., HRONEK, M., HYŠPLER, R., YONG, T., TICHÁ, A., FIKROVÁ, P., HANUŠOVÁ, K., SOJKOVÁ, K., KOPECKÝ, J. and JEDELSKÁ, R. 2010. Relationship between somatic cell count and lactose content in milk of various species of mammals. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 63(2): 87–100.

HOGEVEEN, H., HUIJPS, K. and LAM, T. J. 2011. Economic aspects of mastitis: new developments. *New Zealand Veterinary Journal*, 59(1):16–23.

HUBER, L. 2014. Milch-Güteverordnung (MilchGüV). *Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten*. [Online]. Available at: http://www.lfl.bayern.de/iem/milchwirtschaft/026702/ [Accessed: 2016, December 20].

JONES, G. M. and BAILEY, T. L. 2009. *Understanding the basics of mastitis*. Virginia Cooperative Extension, Publication No. 404–233. Virginia State University.

KOPUNECZ, P. 2016. Milk laboratories - LRM. *Českomoravská společnost chovatelů, a.s.* Available at: http://www.cmsch.cz/343laboratore-pro-rozbor-mleka-lrm/ [Accessed: 2016, December 20].

KOSSAIBATI, M. A. and ESSLEMONT, R. J. 1997. The costs of production diseases in dairy herds in England. *Veterinary Journal*, 154(1): 41–51.

KRÖMKER, V. 2007. *Kurzes Lehrbuch Milchkunde und Milchhygiene*. Parey Verlag, 232.

KVAPILÍK, J. 2014. Mastitis in dairy cows and production losses. [In Czech: Mastitidy u dojených krav a výrobní ztráty.] *Veterinářství*, 64(7): 550–560.

KVAPILÍK, J., HANUŠ, O., BARTOŇ, L., KLIMEŠOVÁ V. M. and ROUBAL, P. 2015. Mastitis of dairy cows and financial losses: an economic meta-analysis and model calculation. *Bulgarian Journal of Agricultural Science*, 21: 1092–1105.

KVAPILÍK, J., HANUŠ, O., SYRŮČEK, J., VYLETĚLOVÁ KLIMEŠOVÁ, M., and ROUBAL, P. 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.

KVAPILÍK, J., JEDELSKÁ, R., HANUŠ, O., URBAN, P., ŘÍHA, J., KOPUNECZ, P., SEYDLOVÁ, R., ROUBAL, P., ZLATNÍČEK, J. and KLIMEŠ, M. 2016. Somatic cell count in milk from individual dairy cows and selected indicators. [In Czech: Somatické buňky v mléce individuálních krav a vybrané ukazatele]. *Mlékařské listy 158*, 27(5): 5–12.

LANDESKONTROLLVERBAND. 2016. *LKV Info – KKB 2016*. [Online]. LKV Nordrhein-Westfalen e.V. Available at: http://www.lkv-nrw.de/fileadmin/redaktion/LKV_NRW/LKV-Info/LKV_Info_KKB_2016.pdf [Accessed: 2016, December 20].

LANDWIRTSCHAFTSKAMMER RHEINLAND-PFALTZ. c2016. Aktuelles zum Milchmarkt. *Landwirtschaftskammer Rheinland-Pfalz*.[Online]. Available at: http://www.lwk-rlp.de/de/markt-statistik/marktbericht/marktbericht/news/detail/News/aktuelles-zum-milchmarkt/ [Accessed: 2016, December 20].

LÜHRMANN, B. 2013. Erkrankungen bei Milchkühen – was kostet eine Mastitis? *Vortrag Milcherzeugertag, Landwirtschaftskammer Niedersachsen.* [Online]. Available at: http://www.lwk-niedersachsen.de/index.cfm [Accessed: 2016, December 20].

MGN MILCHGENOSSENSCHAFT NÖ. 2016. *Mitgliederinformation*. [Online]. Available at: http://www.mgn.at/rundschreiben/rundschreibenDez2016.pdf [Accessed: 2016, December 20].

MILCHINDUSTRIE-VERBAND. 2016. Milkipedia. *Meine Milch*. [Online]. Available at: http://www.meine-milch.de/milkipedia/milch-gueteverordnung [Accessed: 2016, December 20].

MILCHPRÜFRING BAYERN E. V. 2016. *Jahresauswertung 2012–2015. Wolnzach*. [Online]. Available at: https://www.mpr-bayern.de [Accessed: 2016, December 20].

NIELSEN, C. 2009. *Economic impact of mastitis in dairy cows*. Doctoral Thesis. Department of Animal Breeding and Genetics, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, Uppsala.

RÜSCH, P. 2000. Wirtschaftliche Bedeutung – was kostet Mastitis? In: Walkenhorst, M. (Ed.) *Mastitis: Kein Wundermittel gegen die Kuhkrankheit Nummer eins*. Bio Aktuell.

WALKENHORST, M. 2000. Mastitis: Kein Wundermittel gegen die Kuhkrankheit Nummer eins. Bio Aktuell, 9.

ZSCHÖCH, M. 2016. Die Diagnose der Mastitis. *Milchpraxis*, 4: 2–4.

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