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The quality of market milk obtained from farms, employing diverse systems of milking

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The aim of the study was to evaluate quality of commodity milk produced on farms using different milking systems, i.e. hand vs. machine milking (direct to can milking machine, milking pipeline machine, milking parlour). Data from the records of 5 dairy cooperatives operating in the Lubelskie province comprised testing results of 121 872 milk samples. The analyses concerned data from successive months (January to December) in the years 2008-2009 for contents of fat (%) and protein (%), total bacterial count (thousand/ml) and somatic cell count (thousand/ml). It was shown that the adopted milking system, to a considerable extent determined by the herd size and thus related to the milk production technology on the farm, has a significant effect on the quality of commodity milk. Significantly higher ($p \leq 0.01$) fat content was recorded in milk collected in all the machine milking technologies, while analogous differences in protein content were recorded only for milk from the milking parlour system. In terms of microbiological quality the best milk was collected in milking parlours and using direct to can milking machines (average TBC approx. 45 thousand/ml), while the quality was slightly worse in the case of hand milking (47 thousand/ml) and milking pipeline machines (49 thousand/ml). The somatic cell count in hand-milked milk was 2-fold lower (108.6 thousand/ml) that in milk from the other milking systems (194.2-251.9 thousand/ml).

KEY WORDS: commodity milk / cow milking system / fat and protein contents / microbiologicalquality / cytological parameters

In the course of the last two decades we have been observing dramatic structural changes in the Polish dairy industry (both in terms of production and processing), resulting from Poland's accession to the European Union. In the case of milk as raw material these changes were initiated by the new PN-A-86002:1995 standard "Raw milk for wholesale purchase" [6], followed by other EU regulations focusing mainly on the microbiological quality and cytological parameters of milk. Strict requirements have resulted in the gradual elimination of small milk producers, who were unable (primarily for financial reasons)

to adapt to the new binding regulations. Small producers have been replaced by large--scale operators capable of using EU funds for development and modernisation of their farms. Within a period of 10 years (from 1995) the number of milk suppliers decreased by 30%. In the next years this decrease was even more dramatic. In 2007 over 600 thousand farms were involved in milk production, of which approx. 254 thousand produced milk as suppliers of dairies or for directs sale. In 2008 the number of suppliers selling milk to diaries dropped below 200 thousand [12], while in 2010 it was only 170 thousand [16]. In that period the population of cows was further reduced at the simultaneous increase in their productivity per head. Data of the Main Statistical Office [13] show that in 2010 the yield was almost 4810 kg milk per head, whereas in the early 1990's it was only 3300 kg. Significant changes were also observed in the structure of the cow population. Mainly the smallest farms keeping max. 9 cows withdrew from milk production and as a result their number decreased by 1/3, while the number of farms keeping 100-200 cows increased by more than 1/2 [11].

The cow milking system is typically adapted to herd size. Small farms (keeping 1-3 cows) still use hand milking, while with an increase in the head count in the herd more advanced milking systems are used including also milking parlours or the so-called voluntary milking (robotic milking systems) in large loose barns. Fiedorowicz [3] reported that for 50 analysed farms 15 were equipped with direct to can milking machines, 21 had milking pipeline machines, while 14 - milking parlours. Farms equipped with direct to can milking machines kept 16 - 25 cows, those with milking pipeline machines kept 17-55 cows, while milking parlours were found on farms with 46-130 cows.

The aim of the study was to assess quality of commodity milk collected from farms using various milking systems (hand or machine milking: direct to can milking machines, milking pipeline machines and milking parlours).

Material and Methods

Quality of commodity milk was evaluated based on the analyses of data from the records of 5 dairy cooperatives operating in the Lubelskie province. Analysed data concerned contents of (%) and protein (%), total bacterial count (thousand/ml) and somatic cell count (thousand/ml) from individual months (from January to December) in the years 2008-2009.

Data concerned 5065 suppliers, including 855 for dairy A, 1141 for dairy B, 557 for dairy C, 1116 for dairy D and 1396 for dairy E, respectively.

Results were analysed depending on the adopted milking system, i.e. hand milking vs. machine milking (direct to can milking, milking pipeline machine and milking parlour).

Results were analysed statistically using the StatSoft Inc. STATISTICA ver. 6 software, applying one- and two-way analysis of variance with interactions. Significance

of differences between means for the evaluated groups was determined using the Fisher LSD test.

Results and Discussion

The analysis of the effect of milking system on the quality of milk supplied to the dairy showed that with the introduction of more advanced technologies, which is also connected with greater genetic potential of cows and modernised feeding systems, a significant increase is recorded ($p \leq 0.01$) in the contents of fat and protein as well as somatic cell count in milk, which was confirmed in the analyses conducted for each dairy separately (Tables 1 and 2).

The milking system is typically adapted to herd size, and thus also to the volume of milk production from a given farm. Large farms, where technologically advanced milk production systems are applied, including balanced feeding all year round (Total Mixed Ration TMR and Partial Mixed Ration PMR), produce milk with a more advantageous basic chemical composition. These dependencies were confirmed by studies conducted by many authors [1, 7, 8, 15, 17]. For example, Król et al. [8] showed that Simmental cows fed TMR produced by 6.82 kg more milk per day, with the milk containing more fat (by 0.05%) and protein (by 0.13%), including casein (by 0.06%), in comparison to the milk

Table 1
The quality of evaluated raw milk considering the system of milking

Specification		System of milking			
		hand milking	machine milking		
			direct to can	pipeline	milking parlour
Number of samples		15181	56881	45243	4567
Fat (%)	$\bar{x}$	3.71^{A}	4.06^{B}	4.07^{B}	4.07^{B}
	SD	0,55	0.46	0.35	0.31
Protein (%)	$\bar{x}$	3.28^{C}	3.27^{B}	3.26^{A}	3.32^{D}
	SD	0.31	0.25	0.21	0.20
Total bacterial count (thousand/ml)	$\bar{x}$	47.12^{AB}	45.49^{A}	49.18^{B}	45.29^{A}
	SD	164.30	78.27	96.98	24.20
Somatic cell count (thousand/ml)	$\bar{x}$	108.63^{A}	194.15^{B}	248.58^{C}	251.91^{C}
	SD	142.45	155.92	119.28	102.01

A, B, C, D – differences significant at $p \leq 0.01$

Table 2
The quality of milk delivered to individual dairy considering the system of milking

Recipient (Milk plant)	System of milking		Number of samples	Concentration (%)		Total bacterial count (thousand/ml)	Somatic cell count (thousand/ml)
				fat	protein		
1	2	3	4	5	6	7	8
A	1	$\bar{x}$	8791	3.71^{A}	3.24^{B}	30.45^{A}	78.48^{A}
		SD		0.57	0.31	19.30	70.74
	2	$\bar{x}$	10047	3.94^{B}	3.23^{A}	31.39^{B}	95.52^{B}
		SD		0.43	0.25	17.95	71.46
	3	$\bar{x}$	1473	4.04^{C}	3.23^{AB}	29.96^{A}	105.18^{C}
		SD		0.33	0.21	18.73	74.32
	4	$\bar{x}$	462	3.93^{B}	3.27^{B}	34.43^{C}	125.71^{D}
		SD		0.31	0.20	14.90	76.33
B	1	$\bar{x}$	–	–	–	–	–
		SD					
	2	$\bar{x}$	10340	4.11^{A}	3.32^{B}	50.76^{B}	233.90^{A}
		SD		0.44	0.26	164.97	247.95
	3	$\bar{x}$	16805	4.22^{B}	3.30^{A}	33.76^{A}	259.31^{B}
		SD		0.31	0.17	154.85	145.26
	4	$\bar{x}$	251	4.05^{A}	3.43^{C}	31.12^{A}	291.48^{B}
		SD		0.27	0.15	53.63	163.64
C	1	$\bar{x}$	4448	3.51^{A}	3.35^{A}	61.14	127.04^{b}
		SD		0.23	0.29	284.04	203.00
	2	$\bar{x}$	8556	3.57^{B}	3.40^{A}	39.40	103.33^{a}
		SD		0.20	0.28	46.26	130.62
	3	$\bar{x}$	310	3.65^{C}	3.50^{B}	39.37	100.60^{a}
		SD		0.26	0.30	20.23	97.04
	4	$\bar{x}$	72	3.56^{AB}	3.53^{B}	33.10	136.99^{b}
		SD		0.18	0.23	20.82	97.33
D	1	$\bar{x}$	82	3.68^{A}	3.25^{AB}	61.14	266.93^{b}
		SD		0.13	0.29	284.04	97.37
	2	$\bar{x}$	1553	3.78^{A}	3.20^{A}	39.40	235.03^{a}
		SD		0.28	0.28	46.26	107.55
	3	$\bar{x}$	22487	3.92^{B}	3.22^{A}	39.37	246.92^{b}
		SD		0.31	0.23	20.23	96.30
	4	$\bar{x}$	2683	4.03^{C}	3.30^{B}	33.10	253.20^{b}
		SD		0.28	0.21	20.82	79.50

1	2	3	4	5	6	7	8
E	1	$\bar{x}$	1860	4.15^{A}	3.33^{C}	91.58^{C}	201.79^{A}
		SD		0.75	0.35	149.03	169.14
	2	$\bar{x}$	26385	4.27^{B}	3.23^{A}	48.97^{B}	243.12^{B}
		SD		0.40	0.21	39.02	103.20
	3	$\bar{x}$	4168	4.33^{C}	3.28^{B}	44.59^{A}	275.40^{C}
		SD		0.31	0.18	22.66	81.25
	4	$\bar{x}$	1099	4.27^{B}	3.34^{C}	42.25^{A}	297.78^{D}
		SD		0.28	0.17	26.73	94.18
Impact factor	Dairy			xx	xx	xx	xx
	System of milking			xx	xx	xx	xx
	Interaction: dairy x system of milking			xx	xx	xx	xx

Explanatory notes: 1 – hand milking, 2 – direct to can, 3 – pipeline, 4 – milk parlour;
A, B, C, D – difference between systems of milking within the dairy significant at $p \leq 0.01$; a, b, c, d – significant at $p \leq 0.05$; influence of factor ^{xx} – at $p \leq 0.01$

obtained in traditional feeding systems. White et al. [17] reported that in the case of Holstein cows fed TMR daily milk production increased by 9.2 kg, milk fat content increased by 0.10% and lactose content increased by 0.20% in comparison to cows grazing on the pasture. In Jersey cows the differences in terms of fat content amounted to 0.42%, protein content to 0.19% and lactose content to 0.07%, respectively. Also Schroeder et al. [15] showed that Holstein cows fed TMR produced by 1.0 kg/day more milk with greater contents of fat (by 0.46%), protein (by 0.21%) and lactose (by 0.18%) than animals grazing on the pasture and additionally receiving concentrate based on ground maize. Farms applying intensive milk production systems typically keep cows of high-producing breeds (primarily Polish Holstein-Friesian Black-and-White and Red-and-White), which turn out to be more susceptible to udder inflammatory conditions – mastitis (frequently subclinical). This unfortunately results in increased somatic cell counts in milk [10]. A study by Litwińczuk et al. [9] showed that cows of high-producing breeds (Polish Holstein-Friesian Black-and-White and Red-and-White) are more susceptible to a reduction in milk yields and a deterioration of its composition with an increase in somatic cell count. This is indicated by the significantly higher, negative value calculated for these breeds the correlation coefficient between the somatic cell count and milk yield ($r=-0.24$) than in the case of the Simmental and Jersey breeds ($r=-0.12$ and $r=-0.15$).

Results of this study indicate that in terms of microbiological quality the best milk was collected using milking parlours and direct to can milking machines (mean TBC of 45.29

thousand/ml and 45.49 thousand/ml), while the worst quality milk came from milking pipeline machines (mean TBC of 49.18 thousand/ml) – Table 1. Analysis of results conducted separately for each dairy concerning microbiological parameters showed that as a rule the best quality milk was collected in milking parlours, except for dairy A, where the best milk was collected using pipeline machines. In terms of microbiological parameters the worst milk in dairies C, D and E came from hand milking, in dairy B - from direct to can milking machines, while in dairy A it was collected in milking parlours (Table 2). In a similar analysis comparing direct to can milking, pipeline machines and milking parlours Gnyp et al. [5] also stated that with a greater use of more advanced milking technologies the daily milk yields of cows increased (from 20.8 to 22.2 kg), similarly as milk fat (an increase from 4.30 to 4.32%) and protein content (an increase from 3.41 to 3.49%). In turn, the lowest somatic cell count was recorded in milk collected using pipeline machines (400 thousand/ml), while it was highest in the case of direct to can milking machines (556 thousand/ml). Those authors also showed that cows kept in loose barns produced by 0.7 kg more milk with fat content higher by 0.04% and protein content higher by 0.09% in comparison to those in the indoor housing system. However, milk of those cows had inferior values of cytological parameters (SCC 543 thousand/ml and 416 thousand/ml, respectively). When assessing the effect of milking system on cytological parameters of milk Sablik et al. [14] stated for pipeline machines a lower somatic cell count (340 thousand/ml) in comparison to direct to can milking (521.7 thousand/ml). In turn, Danków et al. [2] when comparing mean bacterial counts in milk coming from various milking systems reported the highest TBC in milk from hand milking (1077 thousand/ml), followed by milk from direct to can milking (883 thousand/ml) and milking pipelines machines (128 thousand/ml). The lowest microbial count was recorded in milk collected in milking parlours (100 thousand/ml). Results presented by Fiedorowicz [4] indicate a significant ($r=0.856$) dependence of milk quality (defined based on the classification to grade I, Ekstra and the so-called Super) on the barn functionality index, determined based on occupational safety, animal safety, potential for individual animal handling, difficulty in handling, milking hygiene, reproduction hygiene, feeding lines, milking lines and manure removal lines. Strong negative correlations with barn functionality were also shown for somatic cell count ($r=-0.737$) and bacterial count in milk ($r=-0.845$).

The two-way analysis of variance showed a significant ($p\leq0.01$) effect of milking system on all analysed milk quality parameters. Significant interactions (at $p\leq0.01$) for these parameters were also found between the dairy and milking system (Table 2).

Summing up it needs to be stated that the adopted milking system, which to a considerable degree is adapted to herd size and thus is connected with milk production technology on the farm, has a significant effect on the quality of produced commodity milk. Farms applying technologically advanced milking systems, such as milking parlours, produce milk with the greatest fat and protein contents and high microbiological quality. However, milk collected using such a milking is characterized by slightly inferior cytological parameters.

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