Agronomy Research **14**(1), 33–40, 2016

Effect of cow traffic system and herd size on cow performance and automatic milking systems capacity

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Abstract. The objective of the current study was to investigate automatic milking systems (AMS) to find relationships between cow traffic system and efficiency of the AMS use. Milking records of cows from 11 Estonian dairy farms (46 AMS units) as well as data coming from four Latvian (7 AMS units) and two Polish (4 AMS units) dairy farms were analyzed to determine the system capacity. The highest capacity (milk yield per AMS unit per day) for Feed First cow traffic system (mean ± SD) 1,817 ± 276 kg was indicated in Estonian dairy farms. 142 and 255 kg more milk was obtained, respectively, compared with Milk First and Free cow traffic systems. Overall, average milk yield per cow per day was the highest with Milk First cow traffic system – 31.4 kg. It was 3.3 kg higher than with Feed First and 3.5 kg than Free cow traffic systems. The average machine-on time for milking was highest with Feed First traffic system, i.e. 85.3 ± 6.1%. However, the lower percentage of machine-on time for milking was observed for Free and Milk First cow traffic systems (76.4 ± 10.1% and 73.3 ± 7.2%, respectively).

Key words: AMS capacity, milk production, cow traffic system, Feed First, Milk First, Free cow traffic.

INTRODUCTION

It is possible to give many examples showing dynamic technical and technological progress, which is implemented in agriculture. Automatic milking system (AMS), known also by the acronyms VMS (voluntary milking system) and RMS (robotic milking system) can be named as a most important solutions expressing advance in modern dairy farm. To develop and discuss problems associated with the use of AMS various aspects are taken into consideration in research studies.

The first ideas about fully automated milking process were generated in the mid-seventies and focused on technical improvement of milking system. Topics included in the program of specialist conferences, like Automatic milking – a better understanding (Meijering et al., 2004) confirm that current problems concerning AMS cover socioeconomic aspects, farm and milking system hygiene, animal health, milk quality and abnormal milk, welfare, grazing, farm and herd management (Kic & Nehasilova, 1997; Kic, 1998). All of the mentioned problems and the other ones are the field of detailed research works and assessments to develop knowledge about automatic milking as an integrated system in the dairy farm (Rossing et al., 1998).

One of the most important aspects of the AMS assessment it is efficiency, which can be estimated under current operating and functional conditions (Laurs et al., 2009; Castro et al., 2012). The efficiency constitutes objective of many investigations, where AMS assessment is associated with its capacity (De Koning & Ouweltjes, 2000; Meskens et al., 2001; Artmann, 2004) and expressed by profitability of automatic milking at dairy farms (Cooper & Parsons, 1999; Bijl, 2007).

The efficiency of AMS depends on many factors including technical and technological solutions, like forced traffic in AMS (Bach et al., 2009). The review of cow traffic and milking capacity aspects (Ipema, 1997; Laurs & Priekulis, 2010) can be inspiration to look for higher efficiency of AMS use.

The objective of the current study was to investigate AMS to find relationships between cow traffic systems and efficiency of the AMS use.

MATERIALS AND METHODS

Milking data were obtained from 46 single AMS units placed on 11 dairy cow farms in Estonia. Proper data were also collected in three Latvian dairy farms (equipped with 7 single AMS units) and two Polish dairy farms with four automatic milking systems. One of the Polish dairy farms was equipped with three AMS units (Lely, two A3 Next models and one A4 model) and the second farm with DeLaval VMS model. However Estonian and Latvian dairy cow farms were equipped with only DeLaval VMS model.

Five farms in Estonia had Feed First cow traffic, the rest of four had Free cow traffic and two farms had Milk First cow traffic system. Three Latvian farms had Feed First, while one farm – Milk First cow traffic system. However, one Polish farm had Feed First and the second (with three AMS units) Free cow traffic system.

The computer program DelPro was used to collect data over the period of 14 days per AMS from March 2015 to April 2015 in Estonian farms. Data were recorded over the period of two weeks in 2009 in Latvian dairy farms, while in Polish dairy farms – two weeks in December 2015.

The following records per farm were collected and included into the analysis: number of AMS units, number of cows at milk and total milk yield harvested per day. The data obtained per AMS unit per day were: number of operated cows, milk yield harvested, milkings performed. The results calculated per cow per day were: number of milkings and milk yield harvested. Dataset contained also milking time per one cow (including cows entering the unit, teat cleaning, teat cup attachment, milking, disinfection of the teats and leaving the milking unit) in each dairy farm. Moreover, share of on-time for milking, washing as well idle time were determined. Data gathered in all farms were used to find relationship between capacity of AMS and percentage of on-time for milking. Factors associated with assessment of AMS efficiency were taken to estimate for other relationships in the field of AMS use, i.e. relationship between percentage of on-time for milking and capacity and herd size and milking frequencies.

Acronyms were used to denote proper cow traffic system in the investigated Estonian, Latvian and Polish dairy farms including three groups: FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system.

For each group of dairy farms and particular indices the mean values ± SD were calculated.

Statistical analysis of all collected data was performed using the Statistica v.12 software. Analysis of variance (ANOVA) for main factors was conducted. The statistical model for cow performance included the fixed effects of cow traffic system (Feed First / Free cow traffic and Milk First cow traffic system) and country (Estonia / Latvia / Poland). Significance level was $\alpha = 0.05$. A multiple range test for comparing means in the analysis of variance, i.e. Duncan test was used. Homogeneous groups identified by Duncan test were denoted by a, b and c letters.

RESULTS AND DISCUSSION

Considering data for Estonian dairy farms equipped with AMS (Table 1) it is possible to indicate that the highest capacity expressed by milk yield per AMS unit per day was with Feed First cow traffic system 1817 ± 276 kg (mean ± SD). It was by 142 and 255 kg more than with Milk First and Free cow traffic. The average milk yield per cow per day was the highest with Milk First cow traffic – 31.4 kg. In comparison with Feed First and Free cow traffic it was respectively 3.3 and 3.5 kg higher milk yield. The average AMS on-time for milking was highest with Feed First traffic system – 85.3 ± 6.1%. The lower percentage of on-time for milking was observed for Free and Milk First cow traffic systems – 76.4 ± 10.1 and 73.3 ± 7.2%, respectively.

Comparison of data from Estonian dairy farms (Table 1) showed considerable larger herd size of dairy cows operated by AMS integrated with Feed First traffic system (64.5 ± 4.0 cows) in contrast to the farms with Free and First Milk cow traffic systems (55.7 ± 2.4 and 53.3 ± 4.6 cows, respectively). This can be one of the factor, which explain the highest yield of milk obtained by AMS units per day in farms with Feed First cow traffic system.

The comparison of Estonian dairy farms confirms high production potential of AMS with Feed First cow traffic system. However, the results from Latvian dairy farms equipped with the same cow traffic system and AMS (Table 2) showed that small herd size of cows was operated by AMS (48.0 ± 1.0 cows) as well as low yield of milk gained by AMS units per day – 1,141 ± 159 kg in contrast to 1,817 ± 276 kg in Estonian dairy farms. As a result, it is concluded that Latvian farms don't utilize full potential of AMS and such situation can lead to low effectiveness of AMS and cause therefore financial losses. This is particularly important due to high costs of AMS implementation in dairy farms (Gaworski et al., 2013).

The Polish dairy farm FF1 (Feed First cow traffic system) (Table 3) is comparable with the same characteristics (number of cows per AMS and yield of milk obtained by AMS per day) concerning the same traffic system (Feed First cow traffic) in the Estonian dairy farms. Percentage of time for milking was only variable lower in Polish farm FF1 in comparison with mean value for corresponding Estonian farms FF(1–5) (78.8 vs. 85.3%). The percentage of milking time differs widely between individual farms in all countries. The lowest value (67.7%) was obtained in the Estonian farm FT2 (Free cow traffic system), while the highest value (91.6%) was observed in Estonian farm FF3.

Table 1. Characteristics of different cow traffic systems in the observed Estonian AMS dairy farms

Traffic system / Farm	Number of cows	Number of AMS units	Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield kg AMS^{-1} day^{-1}	Milk yield kg cow^{-1} day^{-1}	Percentage of time for milking	Percentage of time for Idle	Percentage of time for washing
FF1	234	4	58.5	2.55	7.55	1,514	25.9	89.9	6.4	3.7
FF2	253	4	63.3	2.20	7.88	1,741	27.5	76.1	17.9	6.0
FF3	196	3	65.3	2.39	7.65	1,760	27.1	91.6	3.8	4.6
FF4	347	5	69.4	2.23	7.72	2,268	32.7	85.7	10.8	3.5
FF5	132	2	66.0	2.52	7.20	1,802	27.2	83.3	12.3	4.5
(mean ± SD)			**64.5 ± 4.0**	**2.38 ± 0.16**		**1,817 ± 276**	**28.1 ± 2.7**	**85.3 ± 6.1**	**10.2 ± 5.5**	**4.5 ± 1.0**
FT1	218	4	54.5	2.56	7.28	1,434	26.2	71.2	23.2	5.7
FT2	212	4	53.0	2.42	7.50	1,416	26.6	67.7	27.3	5.0
FT3	233	4	58.3	2.59	7.50	1,673	28.6	76.2	17.2	6.7
FT4	456	8	57.0	2.55	7.82	1,724	30.2	90.6	4.9	4.5
(mean ± SD)			**55.7 ± 2.4**	**2.53 ± 0.08**		**1,562 ± 160**	**27.9 ± 1.9**	**76.4 ± 10.1**	**18.1 ± 9.7**	**5.5 ± 1.0**
MF1	200	4	50.0	2.82	6.93	1,541	30.7	68.2	27.3	4.5
MF2	226	4	56.5	2.71	7.33	1,809	32.0	78.4	17.8	3.8
(mean ± SD)			**53.3 ± 4.6**	**2.77 ± 0.08**		**1,675 ± 189**	**31.4 ± 0.9**	**73.3 ± 7.2**	**22.6 ± 6.7**	**4.1 ± 0.5**

FF(1–5) – Feed First cow traffic system, FT(1–4) – Free cow traffic system, MF(1–2) – Milk First cow traffic system.

Table 2. Characteristics of different cow traffic systems in the observed Latvian AMS dairy farms

Farm	Number of cows	Number of AMS units	Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield kg AMS^{-1} day^{-1}	Milk yield kg cow^{-1} day^{-1}	Percentage of time for milking	Percentage of time for idle	Percentage of time for washing
FF1	97	2	48.0	2.71	8.69	1,177	24,5	78.0	18.0	4.0
FF2	94	2	47.0	2.73	8.07	967	20,6	72.0	24.0	4.0
FF3	49	1	49.0	3.00	8.47	1,278	26,1	84.0	10.0	6.0
(mean ± SD)			**48.0 ± 1.0**	**2.80 ± 0.20**		**1,141 ± 159**	**23.7 ± 2.8**	**78.0 ± 6.0**	**17.3 ± 7.0**	**4.7 ± 1.2**
MF1	108	2	54.0	2.89	7.30	1,052	19.5	79.0	15.0	6.0

FF(1–3) – Feed First cow traffic system, MF1 – Milk First cow traffic system.

Table 3. Characteristics of different cow traffic systems in the observed Polish AMS dairy farms

Farm	Number of cows	Number of AMS units	Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield kg AMS^{-1} day^{-1}	Milk yield kg cow^{-1} day^{-1}	Percentage of time for milking	Percentage of time for idle	Percentage of time for washing
FF1	63	1	63.0	2.60	6.48	1,820	28.7	78.8	18.3	2.9
FT1	200	3	66.0	2.50	7.00	1,848	28.0	80.0	15.9	4.1

FF1 – Feed First cow traffic system, FT1 – Free cow traffic system.

Table 4 presents results of analysis of variance for cow and AMS performance, which included the fixed effects of cow traffic system (Feed First / Free cow traffic and Milk First cow traffic system) and country (Estonia / Latvia / Poland).

Table 4. Analysis of variance for cow and AMS performance including all dairy farms

		Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield		Percentage of time for		
					kg AMS^{-1} day^{-1}	kg cow^{-1} day^{-1}	milking	idle	washing
Traffic system	FF	58.8	2.55^{a}	7.75^{a}	1,592	26.7	82.2	13.5	4.3
	FT	57.8	2.52^{a}	7.42^{a,b}	1,619	27.9	77.1	17.7	5.2
	MF	53.5	2.81^{b}	7.19^{b}	1,467	27.4	75.2	20.0	4.8
	p-value	0.1631	0.0496	0.0185	0.2769	0.7330	0.2700	0.3393	0.1526
Country	Estonia	59.3^{a}	2.50^{a}	7.49^{a}	1,698^{a}	28.6^{a}	79.9	15.3	4.8
	Latvia	49.5^{b}	2.83^{b}	8.13^{b}	1,118^{b}	22.7^{b}	78.2	16.8	5.0
	Poland	64.5^{a}	2.55^{a}	6.74^{c}	1,834^{a}	28.4^{a}	79.4	17.1	3.5
	p-value	0.0045	0.0082	0.0004	0.0006	0.0072	0.7773	0.8084	0.1023

FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system
$^{a, b, c}$ – denoted homogenous groups; the different letters a, b and c refer to the significance of difference between the values in column at the level of at least 95%.

Results of analysis of variance show significant difference of mean values ($p < 0.05$) for two factors (milkings per cow per day and milking time) included in the group of compared cow traffic systems. However, results of analysis of variance for cow and AMS performance were significantly differentiated for five factors in cross-section of three compared countries. The percentage of milking time can be recognized as one of the factor characterizing efficiency of the AMS use. It was also pointed out in the investigation performed by Castro et al. (2012), where the capacity of an AMS was expressed in terms of its occupation rate, defined as the percentage of hours the AMS is actually milking per day. It is possible to raise hypothesis that higher percentage of on-time for milking represents higher efficiency of automatic milking system(s) in the farm.

To develop such formulated problem some of the data from the investigated dairy farms were extracted and analysed. Relationship between capacity of AMS (kg of milk milked per day) and percentage of on-time for milking (%) was expressed with a coefficient R^2 (°).

The results show relatively low R^2 values for the analysed relationship between capacity of AMS and percentage of on-time for milking. Only for herds operated by AMS with Free cow traffic system (FT) showed the R^2 value 0.62. Due to low R^2 values of FF and MF systems the overall R^2 value amounted only to 0.15. Such results, especially low R^2 values suggest considerable differences between investigated herds and cows within the herds. The differences can include cow milk yield and cow individual ability to be adapted and operated effective way by AMS.

To estimate AMS effectiveness, it was proposed to find relationship between herd size and percentage of on-time for milking (Table 5). The results indicate on low R^2 values for the analysed relationship between cow herd size operated by AMS unit and percentage of time for milking. Only for herds with Milk First cow traffic system (MF) it was found higher R^2 value (0.83). Another hand there were only three farms with such cow traffic system, therefore, to confirm the relationship it seems to be important to include more records into the analysis.

Table 5. The coefficient R^2 for the relationship between percentage of on-time for milking and capacity and herd size

Solution	No of farms	No of AMS	percentage of on-time for milking	
			capacity of AMS (kg of milk per day)	herd size operated by AMS unit
FF	9	24	0.27	0.24
FT	5	23	0.62	0.23
MF	3	10	0.08	0.83
Total	17	57	0.15	0.25

FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system.

Results of the current observations become part of general discussion on AMS effectiveness, where on-time for particular kind of activities is one of the most important element of the AMS assessment. Relatively low R^2 values concerning the analysed relationships can be effect of many factors (at the same time), which may have effect on AMS milking time. According to Komiya et al. (2002) the milking time depend on milk flow and the milk yield per milking of an individual cow. Moreover, according to the same authors, the milking capacity, (the number of cows which milking robot is able to milk), is determined by the individual performance of the cow and the settings of the system parameters.

Considerable number of factors associated with assessment of AMS efficiency inspires to estimate for other relationships in the field of AMS use. Including data gathered from the 17 farms with AMS in three European countries (Estonia, Latvia and Poland) an effect of cow herd size on milking frequency was found (Fig. 1).

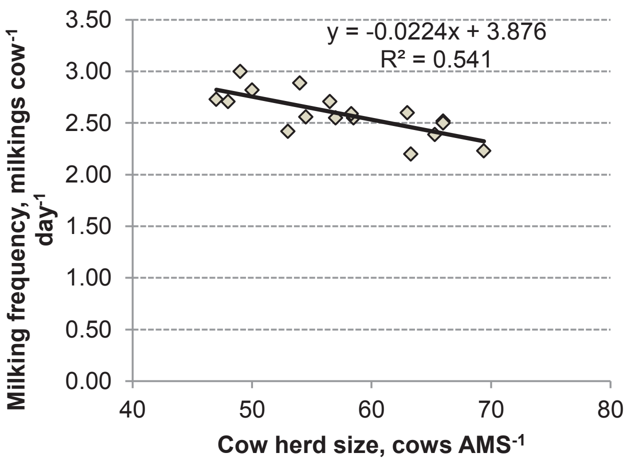

Figure 1. Relationship between herd size and milking frequency.

According to Fig. 1 it is possible to indicate decrease in milking frequency when herd size operated by AMS is increasing. The herd size can explain 54% ($R^2 = 0.54$) from the variability of milking frequencies values. Slightly higher R^2 value ($R^2 = 0.66$) was obtained for the relationship when only farms with Feed First cow traffic system were taken into account (data not presented).

The milking frequency of the cow is quoted as one of the most important factors, which express profits gained from the AMS operation at dairy farms. Higher number of milkings per cow per day lead to increase in annual milk yield per cow (Erdman & Varner, 1995). The milking frequency investigated in current study ranged from 2.20 until 3.00 milkings per cow per day. Obtained range was wider than observed by Gygax et al. (2007), who reported it from 2.38 until 2.56 milkings per cow per day. To compare the frequencies of milkings in more detailed way it must consider the conditions of cow at milking. Bach et al. (2009) found 1.7 until 2.2 and 2.4 until 2.5 milkings per cow per day for Free and Forced cow traffic, respectively. The number of milkings per day per cow ranged from 2.42 to 2.59 for Free cow traffic in Estonian and Polish dairy farms. However, increase in the number of milkings per cow doesn't necessarily mean a greater milk yield per AMS unit (Castro et al., 2012). This finding was confirmed in current study, where dairy farms with Feed First cow traffic system were associated with decrease in capacity of AMS, when number of milkings increasing per cow per day ($R^2 = 0.58$). Many management factors, such as feeding strategy, may determine the success of cow traffic. Such factors might be more important in order to obtain successful cow traffic, than the type of traffic system (Markey, 2013).

CONCLUSIONS

Results of the current study showed that some of the EU countries dairy farms are characterized by high technical and biological potential expressed by number of AMS used per farm and amount of milk produced.

It was possible to indicate the highest capacity, i.e. milk yield per AMS unit per day for Feed First cow traffic system for Estonian dairy farms. The average milk yield per cow per day was the highest with Milk First cow traffic. The average AMS on-time for milking was highest with Feed First traffic system.

The Latvian dairy farms with Feed First cow traffic system operated with small size of cow herds as well as the milk yield by AMS unit per day was low. It is possible to conclude that Latvian farms don't utilize full potential of AMS and this can lead to the low effectiveness of AMS and financial losses.

The Polish dairy farm with Feed First cow traffic system was comparable with mean values (number of cows per AMS and amount of milk milked by AMS per day) concerning the same cow traffic system (Feed First) used in the Estonian dairy farms.

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