ESTIMATING EFFICIENCY IN AUTOMATIC MILKING SYSTEMS

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Abstract. Automatic Milking Systems (AMS), also known as robotic milking, are internationally accepted as a valid alternative to conventional milking parlour, and also as an advanced mean for dairy farm management. The continuous growth of labour and production costs are leading to the development of new improved AMS machines, especially for heaviest milking operations. Accordingly, AMS presence in European dairy farms is expected to continuously grow in the near future. AMS reduces heavy workload and allows milking frequency monitoring of each cow, based on its production level or lactation stage, without any additional labour cost. In this study, milking data of 15 dairy farms located in the Veneto region (North-Eastern Italy) were analyzed with the aim to estimate the Automatic Milking Systems performances, and eventually recognize operative limits and bottlenecks. Results are also of interest to allow definition of relations between the AMS capacity and milking time, which is useful to optimize operations and increase profitability. In particular, data relative to milk yield, daily milking sessions per cow, effective milking time, rejected milking time, cleaning time and machine downtime have been collected and used to evaluate the operative performance of each farm. Specifically, the analysis highlighted an average of 17 $h \cdot day^{-1}$ of milking activity, 5.6 $h \cdot day^{-1}$ of inactivity and 1.4 $h \cdot day^{-1}$ for cleaning and self-diagnosis. Additionally, 40 % of the AMS reported the use for milking activities lower than 16 $h \cdot day^{-1}$ with idle periods exceeding in some cases 7-8 $h \cdot day^{-1}$.

Keywords: automatic milking system; efficiency; milking frequency; dairy housing system.

Introduction

Application of automatic technologies is a growing trend in agriculture [1; 2] and in the livestock sector [3; 4], and plays an active role in the future prospects [5; 6]. The introduction of Automatic Milking Systems (AMS) is one of the most important technological changes in the dairy housing system [7], which can be considered not only as a substitute for milking parlors, but also as a new approach to manage dairy farms. Originally, the interest in this technology depended on the rising cost of labour, land, buildings and machinery combined with the decrease of milk prices [8; 9]. In fact, since 2009 about 8,000 farms have installed AMS [10], and nowadays they can be considered as a well-established technology. The main factors, which promote the introduction of AMS for dairy cows, are: improved work organization, increase in milk yields and improvement in animal behavior [11]. AMS reduces heavy-workload and allows milking frequency monitoring of each individual cow, based on its production level or lactation stage, without any additional labour costs [12]. Everything else remains unchanged, the cows milked more frequently during lactation, normally produce more milk than the cows milked twice a day [13]. Even if many factors can affect the behavior of dairy cows on a farm, the cows milked by AMS can carry out their daily activities with more freedom and have more interaction opportunities with their environment [14]. However, efficiency is one of the most important aspects of AMS evaluation; in fact, it can be estimated with the current operative and functional conditions [15]. The efficiency is the aim for many studies, in which the AMS evaluation is associated with its working capacity [16] and is expressed by the profitableness of automatic milking on dairy farms [17; 18].

In this study, milking data of 15 dairy farms with AMS located in the Veneto region (North-Eastern Italy) were analyzed in order to evaluate the system performance according to the actual dairy organization. In detail, data about: milk yield, daily milking sessions per cow, effective milking time, rejected milking time, cleaning time and machine downtime have been collected and used to evaluate the operative performance of each farm.

Materials and methods

Milking data were collected during the year 2016 (January 2016 to December 2016) from 15 commercial dairy farms with AMS located in the Veneto region (North-Eastern Italy). The farms were characterized by a free-stall system, which houses 61 ± 12 lactation cows (mean ± SD) and the prevalent breed was Holstein-Friesian. In each dairy farm, the same AMS model (single unit system) was available, with only negligible differences due to specific machine personalization (mainly in

terms of data logging frequency, washing solution, dimensions of some components). The systems were positioned in the center of the stable and cows had free access to AMS all day long without selection gates or holding restraint areas (free cow traffic system). The cows were fed twice a day with a ration composed by cereal silage, maize flour, concentrate and hay. While concentrate was supplied from the automatic dispenser based on daily milk production data, provided by AMS, the remaining components were mixed to obtain a Total Mixed Ration (TMR). The data collected in all farms were used in order to recognize relationships between the AMS capacity and milking time. Factors associated with AMS efficiency evaluation were used to estimate other relations about the AMS application field, i.e. relation between percentage of on-time for milking, capacity and herd size and milking frequencies.

The following data were collected for each dairy farm taking advantage of the AMS management software.

- Milking performance: milk yield (kg·milking^{-1}); milking duration, i.e. the time between cow identification and the last teat-cup detachment (min·milking^{-1}).
- Cow performance: milking (no·cow·day^{-1}); milk yield (kg·cow·day^{-1}); duration (min·cow·day^{-1}).
- AMS performance: milking (no·day^{-1}); milking duration (h·day^{-1}); idle time (h·day^{-1}); washing time (h·day^{-1}); milk yield (kg·day^{-1}); average milk flow rate (kg·min^{-1}).

Results and discussion

Table 1 shows the statistical data for the samples in the study. Overall, 53 % of the dairy farms had a milking frequency ≥ 2.5 times·day^{-1} and 6,6 % had a milking frequency ≤ 2.0 times·day^{-1}. The milking frequency of 2.4 milking·day^{-1} was the most common (20 % of cases).

These values are similar to those for milking cows, where the average milking frequency varied between 2.3 and 2.8 [19; 20]. The average milk production among the 15 farms resulted to be 1,947 kg·AMS·day^{-1} with production per head just over 30 kg·day^{-1}.

Table 1

Performance of dairy cows in the 15 farms investigated

Dairy Farm	Cow herd size		Lactation Cows·AMS^{-1}		Milk yield , kg·AMS^{-1}·day^{-1}		Milkings , no·cow^{-1}·day^{-1}		Cow yield , kg·cow^{-1}·day^{-1}	
	Min	Max	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	47	57	51	2.6	1,841	171	2.8	0.2	36.0	2.3
B	55	64	61	1.4	1,917	167	2.8	0.3	31.2	2.6
C	71	84	82	6.9	2,401	256	2.1	0.2	26.0	2.5
D	55	72	66	3.5	2,506	121	2.5	0.2	37.5	1.9
E	53	61	59	1.4	1,590	257	2.7	0.4	26.6	4.1
F	47	69	57	3.0	2,217	173	2.9	0.2	39.7	3.0
G	57	67	64	2.2	1,760	327	2.4	0.3	27.4	2.7
H	46	69	58	3.6	1,626	101	2.6	0.2	27.7	1.7
I	31	45	38	4.8	1,375	291	3.0	0.2	35.7	4.3
L	51	64	59	3.0	1,941	235	2.5	0.3	32.5	3.9
M	40	60	48	5.7	1,542	148	2.6	0.2	31.8	3.4
N	66	75	70	3.0	2,376	150	2.4	0.2	33.8	2.1
O	70	78	74	1.6	2,672	167	2.4	0.1	35.9	2.0
P	47	53	49	1.4	1,786	121	3.3	0.3	36.2	2.6
Q	58	84	76	8.0	1,661	350	1.7	0.2	21.5	2.9
Mean	52.9	66.8	60.8	3.47	1,947	202	2.6	0.23	31.97	2.80
SD	10.8	11.0	11.7	-	394	-	0.4	-	5.15	-

By the analysis of the operative time of the milking robot in the 15 farms (Table 2) each AMS presents on average: 17 h·day^{-1} of milking activity, 5.6 h·day^{-1} of inactivity while 1.4 h·day^{-1} for

cleaning and self-diagnosis. However, 40 % of the AMS presented a use for milking activities under 16 h·day^{-1} with idle periods that sometimes even exceed 7-8 h·day^{-1} (Fig. 1).

Milking time per cow resulted of 6.6 min·cow^{-1} with an average milk flow rate of 4.9 kg·min^{-1}. Only 13 % of the dairy farms have presented a milking time longer than 8 min·cow^{-1}.

From the analysis of the chronological accesses to AMS, it is possible to obtain important information on performance. In fact, as we can see from Tab. 3, the average number of milking sessions in the farms has proven to be equal to 156. Almost irrelevant in terms of time were the fail milkings, while the rejected ones (83·AMS^{-1}·day^{-1}) are an important share, which will certainly go to impact on the performance and indirectly also on the operative availability of the AMS.

On average the share of accesses with the next milking session represents 65 % of the AMS operations (Fig. 2), while the share of rejected ones amounted to 33.8 % of total AMS utilization time. Not particularly significant is the share of fail milkings (1.1 %).

Table 2

Analysis of AMS performance in the 15 farms investigated

Dairy Farm	Milking time , h·AMS^{-1}·day^{-1}		Idle time , h·AMS^{-1}·day^{-1}		Washing time , h·AMS^{-1}·day^{-1}		Milking time , min·cow^{-1}	Average milk flow rate , kg·min^{-1}
	Mean	SD	Mean	SD	Mean	SD	Mean	Mean
A	15.4	0.05	7.4	0.05	1.2	0.05	6.5	5.6
B	16.9	0.06	6.1	0.07	1.1	0.07	6.0	5.2
C	20.1	0.09	2.2	0.10	1.7	0.10	7.1	3.6
D	20.2	0.05	2.8	0.04	1.0	0.05	7.2	5.2
E	12.4	0.12	9.1	0.13	2.5	0.13	4.7	5.7
F	18.3	0.05	4.2	0.05	1.5	0.05	6.7	5.9
G	18.2	0.08	4.1	0.09	1.7	0.09	7.0	3.9
H	17.5	0.04	5.4	0.05	1.1	0.05	6.9	4.0
I	15.9	0.10	7.0	0.10	1.1	0.10	8.3	4.3
L	12.3	0.08	10.5	0.09	1.2	0.09	5.1	6.4
M	17.5	0.06	5.1	0.06	1.4	0.06	8.4	3.8
N	15.1	0.05	7.3	0.06	1.6	0.06	5.4	6.3
O	18.6	0.04	3.8	0.04	1.6	0.04	6.2	5.8
P	20.6	0.04	2.6	0.05	0.8	0.05	7.6	4.7
Q	15.2	0.10	6.5	0.10	2.3	0.10	6.9	3.1
Mean	16.95	0.07	5.61	0.07	1.45	0.07	6.67	4.90
SD	2.58	-	2.41	-	0.47	-	1.06	1.06

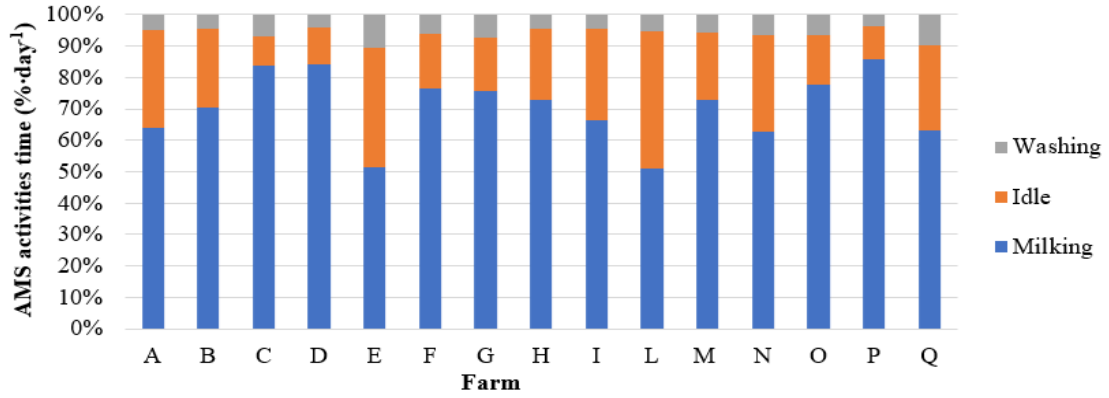

Fig. 1. **Distribution of the 3 main AMS activities time during 24 hours (A)**

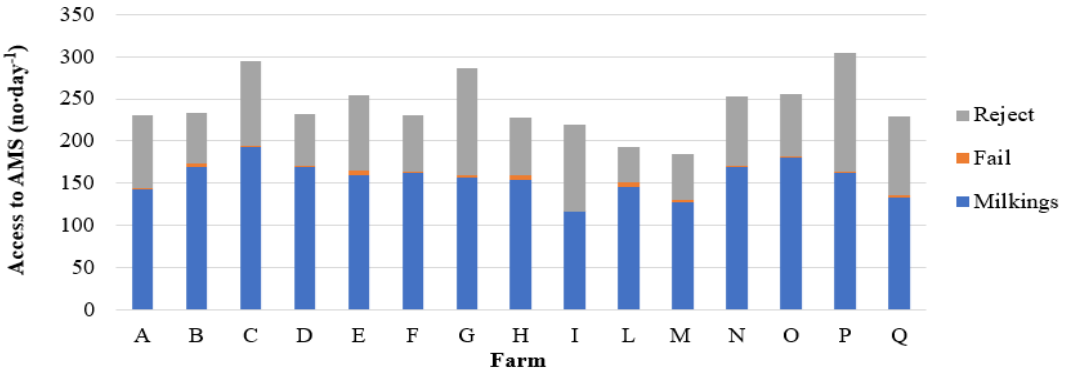

Fig. 2. **Average daily accesses in the 15 AMS farms investigated**

Table 3

Average daily values of milkings, fail milkings and reject for AMS

Dairy Farm	Milkings, no·AMS^{-1}·day^{-1}		Fail milkings, no·AMS^{-1}·day^{-1}		Reject, no·AMS^{-1}·day^{-1}		Milkings, % of time	Fail milkings % of time	Reject, % of time
	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	Mean
A	143	12.3	2	0.05	86	0.05	61.9	0.9	37.2
B	170	15.3	4	0.07	60	0.07	72.6	1.7	25.6
C	193	21.6	1	0.10	100	0.10	65.6	0.3	34.0
D	169	9.0	2	0.04	61	0.05	72.8	0.9	26.3
E	160	29.3	5	0.13	89	0.13	63.0	2.0	35.0
F	162	25.9	2	0.05	66	0.05	70.4	0.9	28.7
G	157	12.1	2	0.09	127	0.09	54.9	0.7	44.4
H	154	18.1	5	0.05	69	0.05	67.5	2.2	30.3
I	116	13.2	1	0.10	103	0.10	52.7	0.5	46.8
L	146	18.4	5	0.09	42	0.09	75.6	2.6	21.8
M	127	16.3	3	0.06	55	0.06	68.6	1.6	29.7
N	169	14.3	2	0.06	82	0.06	66.8	0.8	32.4
O	180	13.3	2	0.04	74	0.04	70.3	0.8	28.9
P	162	6.3	2	0.05	140	0.05	53.3	0.7	46.1
Q	133	11.8	3	0.10	93	0.10	58.1	1.3	40.6
Mean	156.1	15.81	2.7	0.07	83.1	0.07	64.94	1.19	33.85
SD	20.4	-	1.4	-	26.8	-	7.38	-	7.75

The comparison of average AMS performance per cow (Fig. 3) shows that, on a daily basis, the share of milking sessions per cow is 2.62, the one of fail milkings is 0.05, while the one of reject is 1.43. However, the correct management of this last important operative parameter results important in order to increase the share of the AMS productivity.

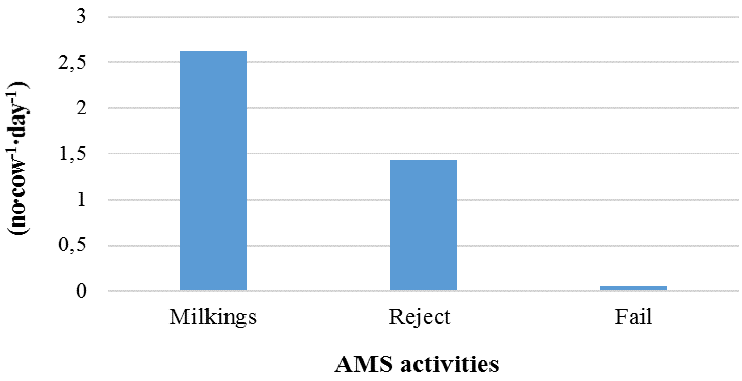

Fig. 3. **Number of daily milkings, reject and fail per cow**

The result of the current observations becomes part of the general discussion about the efficiency of AMS. 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. However, practical utilization of the automated milking systems covers only a 65-85 % of the working time due to connection failures, cleaning down times and other technical problems [21]. This suggests that it is reasonable to expect that on an average day, only 19 of the 24 hours are available for successful milkings. Achievement of higher occupancy rates (ideally 100 %) have to include consideration on the technical aspects of the implemented machines, but are not limited to that: indeed, other aspects have also to be considered, mainly related to the feeding strategy, cow behavior and cow traffic.

The analysis of the collected data in all farms has allowed to find a relation between the AMS capacity and the milking time; in fact, an effect of the cow herd size was found on the milking frequency in 15 farms that actively use AMS. According to Fig. 4 it is possible to indicate a decrease in the milking frequency when the herd size operated by AMS is increasing. However, increase in the number of milkings per cow does not necessarily mean a superior milk yield per AMS unit [22; 23].

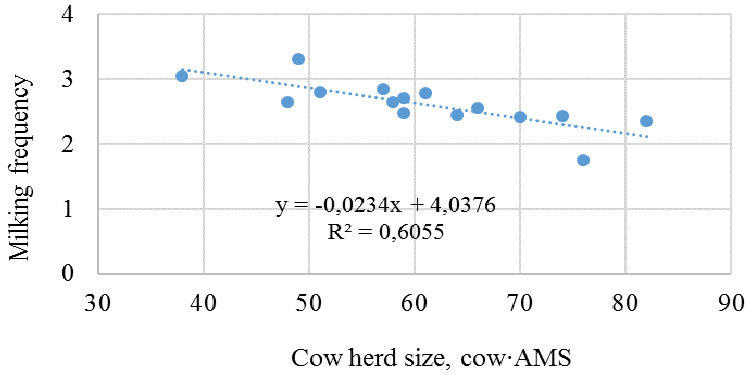

Fig. 4. **Relation between the milking frequency and the cow herd size**

Conclusions

In the current study, milking data of 15 dairy farms with AMS located in Veneto region (North-Eastern Italy) were analysed, in order to estimate the system capacity in each farm under actual dairy organization.

1. Notwithstanding the number of the daily milkings examined, it is in line with the studies existing in literature, which positively influence 65 % of daily operative time, the management of "reject" is very important that actually makes AMS unproductive for almost 34 % of the day.
2. This last parameter, while it may represent an important key to adapt the animals to the new milking routine, on the other hand, if such system is not carefully handled, could reduce the performance of the AMS.
3. However, many other management factors, such as the feeding strategy, cow traffic, stable layout and the cow herd size, may potentially influence the operative performance of the AMS.

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