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Analysis of electric energy consumption of automatic milking systems in different configurations and operative conditions

Aldo Calcante,* Francesco M. Tangorra,†[1] and Roberto Oberti*
*Department of Agricultural and Environmental Sciences, Università degli Studi di Milano, Via Celoria 2, 20133 Milan, Italy
†Department of Health, Animal Science and Food Safety, Università degli Studi di Milano, Via Celoria 10, 20133 Milan, Italy

ABSTRACT

Automatic milking systems (AMS) have been a revolutionary innovation in dairy cow farming. Currently, more than 10,000 dairy cow farms worldwide use AMS to milk their cows. Electric consumption is one of the most relevant and uncontrollable operational cost of AMS, ranging between 35 and 40% of their total annual operational costs. The aim of the present study was to measure and analyze the electric energy consumption of 4 AMS with different configurations: single box, central unit featuring a central vacuum system for 1 cow unit and for 2 cow units. The electrical consumption (daily consumption, daily consumption per cow milked, consumption per milking, and consumption per 100 L of milk) of each AMS (milking unit + air compressor) was measured using 2 energy analyzers. The measurement period lasted 24 h with a sampling frequency of 0.2 Hz. The daily total energy consumption (milking unit + air compressor) ranged between 45.4 and 81.3 kWh; the consumption per cow milked ranged between 0.59 and 0.99 kWh; the consumption per milking ranged between 0.21 and 0.33 kWh; and the consumption per 100 L of milk ranged between 1.80 to 2.44 kWh according to the different configurations and operational contexts considered. Results showed that AMS electric consumption was mainly conditioned by farm management rather than machine characteristics/architectures.
Key words: automatic milking system, electric energy consumption, dairy farm management

INTRODUCTION

Automatic milking has been a revolutionary innovation in dairy cow farming. Switching from conventional milking to automatic milking results in big changes for both the farmers and the animals, requiring a different concept of herd management. The labor routine and the cow behavioral routine are modified, some conventional tasks are cancelled, while new activities become necessary (Spahr and Maltz, 1997). Changing of the nature of labor and computerized monitoring of individual animals are probably the greatest innovations related to robotic milking. Moreover, automatic milking enables milking frequency to be controlled on an individual cow basis, according to her production level or stage of lactation, without incurring extra labor costs. All else being equal, cows milked more frequently throughout a lactation usually tend to produce greater amounts of milk compared with cows milked twice a day (Castro et al., 2012; Jacobs and Siegford, 2012; Stelwagen et al., 2013; Wright et al., 2013). These aspects offer many potential advantages, while at the same time opening new challenges with the potential for a major drawback. The initial investment can be greater than that for a traditional system, and robotic equipment may not last as many years (Rotz et al., 2004). Thus, when deciding between investing in automatic or conventional milking systems, dairy producers must weigh the decreased labor needs of the automatic milking system (**AMS**) against the increased fixed costs (Jacobs and Siegford, 2012). Furthermore, an accurate analysis of the AMS operational costs has to be carried out considering that electric consumption is one of the most relevant and uncontrollable balance items, ranging between 35 and 40% of the total annual operational costs.

More than 10,000 dairy cow farms worldwide use AMS to milk their cows and this figure is expected to grow in the next years (de Koning, 2011; Lyons et al., 2014), increasing the energy consumption related to AMS. On the other hand, the removal of the milk quotas in the European Union in 2015 is likely to increase milk production per farm, possibly generating a drop in the milk price (Lips and Rieder, 2005; Bouamra-Mechemache et al., 2008). Therefore, dairy farmers have to focus on cost control of the milk production system and the efficient use of energy as one way to improve the cost competitiveness. Quantifying energy consumption is essential to achieve this objective.

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[1]Corresponding author: francesco.tangorra@unimi.it

Different studies (Artmann and Bohlsen, 2000; Bijl et al., 2007) showed greater electricity costs with AMS in comparison to conventional milking systems, although these studies did not give detailed component breakdown information. Electricity and water consumption of AMS and conventional milking parlor were investigated in a farm test by Rasmussen and Pedersen (2004). A more recent study by Upton and O'Brien (2013) analyzed the energy consumption of an AMS as operated within a grass-based, seasonally calved dairy production in Ireland, highlighting that the largest energy-demanding processes associated with milk harvesting in the AMS were heating water, compressing air, and cooling milk.

Compared with previous studies, new AMS have been launched and previous models have been improved in recent years. The energy used by AMS depends on many factors (e.g., machine generations, machine configurations and settings, and operative conditions). The aim of the present study was to investigate the electricity consumption of 2 subsequent generations of the most diffused AMS installed in dairy farms of Northern Italy (about 80% of the current installations). The focus was to measure the electric consumption of these AMS under practical conditions in different operational contexts.

MATERIALS AND METHODS

The study was carried out at 4 dairy farms, all located in Lombardy Region (Northern Italy) and equipped with Lely Astronaut A3 Next (Lely Holding, Maassluis, the Netherlands) single box (farm 1) and Lely Astronaut A4 (Lely Holding) with a central unit featuring a central vacuum and cleaning system for one cow unit (farm 2) or 2 cow units (farm 3 and farm 4). All tests were carried out in the same period (winter 2014). The main characteristics and settings of the AMS tested are summarized in Table 1.

Free cow traffic was adopted in all the farms. Vacuum for milking was supplied by a frequency-controlled lobe vacuum pump powered by a 1.1- and 1.3-kW motor for the A3 and A4 AMS, respectively. Compressed air for opening/closing the entrance and exit gates of the milking stall and for moving the robotic arm toward the udder was supplied by a 3.7-kW scroll compressor (SF4, Atlas Copco AB, Stockholm, Sweden) in the A4 milking systems installed in farms 2, 3, and 4. A 7.5-kW rotary screw compressor (K-MID 10, Fini Nuair S.p.A., Turin, Italy) was used in the A3 installed in farm 1. In the latter case, the air compressor served a second unit A3 not involved in the test, so its electricity consumption was shared equally between the 2 units. All the AMS were equipped with the Pura steam cleaning system (Lely Holding) to clean the milk unit with hot steam (temperature about 150°C) between every milking. The Pura system of the A4 installed in farm 3 was disabled as decided by the farmer, and the milk unit was cleaned only with water at room temperature between every milking.

Experimental Measurements

All AMS were powered by Three-Phase 380 V/50 Hz. The electrical power absorbed by each AMS (milking unit + air compressor) was measured using 2 three-phase power and energy analyzers Qualistar CA 8334 with internal memory (Chauvin Arnoux Metrix, Paris, France) applied to the AMS and to the compressor electricity panels (Figure 1A). In the energy use of AMS milking unit are included vacuum and milk pumps, electric and electronic devices (printed circuit board, touch screen, frequency inverter, and so on), actuators, water heater, and steam cleaning system.

The Power and Energy Analyzer used alligator clips and current clamps connected to each phase line and neutral to measure, respectively, voltages and currents. To operate safely and in agreement with the International Electrotechnical Commission, between the AMS electricity panel and both the milking unit and the air compressor, a 5-pole 16 A International Electrotechnical Commission extension plug was inserted and, on the same extension plug, the alligator clips and current clamps were connected (Figure 1B).

Table 1. Main characteristics and settings of the automatic milking system (AMS) monitored

Item	Cows milked	AMS[1]	Control unit	Milking unit	Installation date	Working vacuum (kPa)	Pulsation frequency (beats/min)	Pulsation rate
1	61	A3 Next	1	1	2010	43	60	65:35
2	68	A4	1	1	2013			
3	117	A4	1	2	2012			
4	117	A4	1	2	2013			

[1]A3 Next = Lely Astronaut A3 Next (Lely Holding, Maassluis, the Netherlands); A4 = Lely Astronaut A4 (Lely Holding).