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Daily and seasonal trends of electricity and water use on pasture-based automatic milking dairy farms

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ABSTRACT

The objective of this study was to identify the major electricity and water-consuming components of a pasture-based automatic milking (AM) system and to establish the daily and seasonal consumption trends. Electricity and water meters were installed on 7 seasonal calving pasture-based AM farms across Ireland. Electricity-consuming processes and equipment that were metered for consumption included milk cooling components, air compressors, AM unit(s), auxiliary water heaters, water pumps, lights, sockets, automatic manure scrapers, and so on. On-farm direct water-consuming processes and equipment were metered and included AM unit(s), auxiliary water heaters, tubular coolers, wash-down water pumps, livestock drinking water supply, and miscellaneous water taps. Data were collected and analyzed for the 12-mo period of 2015. The average AM farm examined had 114 cows, milking with 1.85 robots, performing a total of 105 milkings/AM unit per day. Total electricity consumption and costs were 62.6 Wh/L of milk produced and 0.91 cents/L, respectively. Milking (vacuum and milk pumping, within-AM unit water heating) had the largest electrical consumption at 33%, followed by air compressing (26%), milk cooling (18%), auxiliary water heating (8%), water pumping (4%), and other electricity-consuming processes (11%). Electricity costs followed a similar trend to that of consumption, with the milking process and water pumping accounting for the highest and lowest cost, respectively. The pattern of daily electricity consumption was similar across the lactation periods, with peak consumption occurring at 0100, 0800, and between 1300 and 1600 h. The trends in seasonal electricity consumption followed the seasonal milk production curve. Total water consumption was 3.7 L of water/L of milk produced. Water consumption associated with the dairy herd at the milking shed represented 42% of total water consumed on the farm. Daily water consumption trends indicated consumption to be lowest in the early morning period (0300–0600 h), followed by spikes in consumption between 1100 and 1400 h. Seasonal water trends followed the seasonal milk production curve, except for the month of May, when water consumption was reduced due to above-average rainfall. This study provides a useful insight into the consumption of electricity and water on a pasture-based AM farms, while also facilitating the development of future strategies and technologies likely to increase the sustainability of AM systems.
Key words: automatic milking system, pasture-based system, electricity consumption, water consumption, sustainability

INTRODUCTION

The abolition of the European Union (**EU**) milk quota regimen has presented EU dairy farmers with the opportunity to increase milk production for the first time in over 3 decades. Irish milk production was predicted to have the potential to increase by 50% on pre-quota abolition levels (DAFM, 2010), with the value of that product also predicted to increase (DAFM, 2015). This increase in production is due primarily to the current underutilization of existing animals and lands (O'Donnell et al., 2008). Additional milk production may result in a milk price reduction (Lips and Rieder, 2005) and increased milk price volatility (Dillon et al., 2016). By the end of 2016, milk production had increased by 35% over the Food Harvest 2020 baseline milk production levels (CSO, 2017); placing a substantial strain on existing dairy farm labor resources. This, in combination with the shortage of available skilled labor (Teagasc, 2017), has resulted in farmers adopting new technologies to reduce labor demand. One such technology, automatic milking (**AM**) systems, are being adopted to automate the milking process. This adoption is facilitated by innovative pasture-management methods (Lyons et al., 2013), which enable pasture-based farmers to maintain a large portion of grazed grass in the cow diet. Auto-

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matic milking systems have been found to reduce labor (Mathijs, 2004; Bijl et al., 2007; Shortall et al., 2016) and give greater time flexibility to the farm manager.

However, a significant limitation associated with the adoption of AM is the reduced profitability of the technology relative to conventional milking (**CM**) technologies of low to medium specification (Rotz et al., 2003; Jago et al., 2006; Shortall et al., 2016). Although the large capital cost associated with AM technology is one of the main factors contributing this, the increased consumption of electricity associated with AM may also be considered a contributing factor (Bijl et al., 2007; Upton and O'Brien, 2013). Whereas the consumption of electricity by both AM (Upton and O'Brien, 2013; Calcante et al., 2016) and CM systems (Upton et al., 2013) have been previously determined, the daily and seasonal trends of electricity consumption in a pasture-based AM systems remain undocumented. Furthermore, electricity consumption can be influenced by on-farm equipment, and the possibility exists to reduce electricity costs through the adoption of energy efficient and renewable technologies. However, the financial prudence of these technologies will be dependent not alone on the capital costs of these technologies, but also on the daily trends of electricity consumption (Upton et al., 2015a).

Water is commonly used to precool milk on AM farms via a tubular cooler; hence, water consumption on AM farms may be significant. It is important to measure water consumption to gain a holistic picture of the energy water nexus on AM farms, as this is essential for comparing equipment efficiencies across farms. Furthermore, on-farm water consumption is necessary background information for the computation of a farm's water-footprint. These data were presented by Murphy et al. (2017) for Irish CM dairy farms; however, information relating to on-farm water usage on AM pasture-based systems remains scant. Although Higham et al. (2017) outlined the trends in water consumption on New Zealand pasture-based CM farms, water consumption in an AM systems has only been reported in relation to the milking area by Artmann and Bohlsen (2000), thus leaving the whole farm and the daily and seasonal trends undocumented. Water use also has a direct effect on electricity costs, as there is an associated cost of pumping water. Thus, the objective of our study was to establish the daily and seasonal trends of electricity and water consumption on AM dairy farms in pasture-based systems over a year-long period.

MATERIALS AND METHODS

This study was conducted on 7 pasture-based AM farms with a spring-calving system across Ireland. These farms were selected from a database of clients associated with the extension and advisory section of the Teagasc research, training, and advisory body in Ireland. To be considered for selection, farms had to be pasture-based, spring-calving, milking with an AM system for at least 1 yr, and willing to have electricity and water meters installed within their existing infrastructure.

Data Collection

Data were collected for the 12-mo period from January 1 to December 31, 2015. Electricity and water consumption was recorded using a wireless monitoring system supplied by Carlo Gavazzi (Carlo Gavazzi Automation SpA, Lainate, Italy). Wireless, wide area network routers were used to transport the data from farm to research center, where Powersoft logging and recording software (Carlo Gavazzi Automation SpA) calculated cumulative energy used (kWh) at 15-min intervals for each on-farm electricity- and water-consuming process. Dairy farm processes and equipment that were metered for electrical consumption included milk cooling components, air compressors, AM unit(s), auxiliary water heaters, water pumps, and others, such as lights, sockets, automatic manure scrapers, and so on. On-farm direct water-consuming processes that were metered included AM unit(s), auxiliary water heaters, tubular coolers, wash-down water pumps, livestock drinking water supply, and miscellaneous water taps.

The AM systems were arranged in both single and double unit configurations. A single unit configuration consisted of 1 milking crate, 1 robotic arm, and 1 central compartment housing the pumping and cleaning systems. A double unit configuration consisted of 2 milking crates, 2 robotic arms, and 1 central compartment housing the pumping and cleaning systems for both milking crates. For the purpose of the study, the term AM unit is the equivalent of 1 milking crate. Thus, when output and consumption are expressed per AM unit, it refers to the total AM system consumption divided by the number of milking crates (e.g., double configuration is divided by 2). The compartmentalization of the milk pump, vacuum pump and water heater, along with individual hot and cold water supplies within the AM system did not allow for individual metering of these components on 6 of the 7 study farms. Thus, the electrical consumption and cost data presented in our study for milking is the combined consumption and cost of milk pumping, milking vacuum, and water heating within the AM system. Water consumption data for milking is the combined consumption of both hot and cold water for cleaning of the AM plant.