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Analysis of energy consumption in robotic milking

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Abstract

This study aims to document the energy consumption of an Automatic Milking System (AMS) as operated within a grass based seasonally calved dairy production in Ireland. The data and information collected will be used to i) describe the energy consumption of the AMS, ii) examine consumption of individual energy consuming components within the milking system, iii) compare energy consumption of AMS and conventional milking systems. Energy consumption in AMS milk production is a topical issue because these systems are becoming more popular worldwide (more recently even in grazing systems), however there has been little analysis of how on-farm energy use changes when a farm adopts an AMS in place of a conventional herringbone type milking system. Our objectives, therefore, were to document electricity used per litre (l) of milk sold as a farm makes the transition from milking in a herringbone milking parlour to milking in an AMS and to identify the relative share of energy consumption among the energy consuming components of the milk harvesting process.

Keywords: energy use, milk production, automatic milking

Introduction

Recent data shows that there are approximately 10,000 commercial farms worldwide using automatic milking systems (AMS) to milk their cows. This figure is expected to grow rapidly in the coming years (De Koning, 2011). Therefore, the energy consumption of AMSs will become increasingly important. Studies by Bijl *et al,* (2007), and Artmann & Bohlsen, (2000), showed that electricity costs were greater with AMSs compared to conventional milking systems. However these studies focused of indoor dairy herds and did not give detailed component breakdown information.

The removal of the milk quota system in the European Union in 2015 is likely to increase milk production per farm and to decrease milk price (Bouamra-Mechemache *et al.*, 2008; Lips *et al.*, 2005). In Ireland, for example, milk production per farm is expected to increase by 50% by 2020 (DAFM, 2010), whereas milk price is expected to decrease by 33% (Lips *et al.*, 2005). Milk production systems in Ireland, therefore, will focus on cost control and maximising the amount of milk that is produced from grazed grass. The potential of Irish soils to grow grass throughout the year and efficiency in utilizing grass are key factors affecting output and profitability of dairy production systems (Shalloo *et al.*, 2004).

Efficient use of energy is one way to improve the cost competitiveness of the Irish dairy sector. At this moment, electricity costs on Irish farms are around 4% of variable on-farm costs (Upton *et al.*, 2011), but they are expected to increase because of rising global energy costs and the introduction of a dynamic electricity pricing structure for 80% of electricity consumers in Ireland by the year 2020. Thus, reducing electricity consumption will reduce production costs, but it also has an environmental benefit, because electricity consumption has been shown to represent 25% of total primary energy use on pasture-based dairy farms in New Zealand (Wells, 2001). Hence understanding electricity consumption among varying milking systems will contribute to the debate on robotic versus conventional milking and help farmers and advisors to make informed decisions. There is a plethora of social and economic reasons why a farmer would choose to install a robotic milking system, however this paper will focus on electricity consumption running costs alone.

The aim of this study was to document electricity used per litre of milk sold as a farm makes the transition from milking in a herringbone milking parlour to milking in an AMS and to identify the relative share of energy consumption among the energy consuming components of the milk harvesting process.

Materials and methods

Farm system description

This study was carried out on a dairy research farm at Teagasc Moorepark in Ireland. Data collection was undertaken from May to October during 2010, 2011 and 2012. Over these periods all relevant inputs and outputs were recorded using a combination of wireless data transfer and manual recording. Data recorded included milkings per cow per day, milk yield and milk quality parameters such as total bacteria count (TBC) and somatic cell count (SCC). The energy consumption of the milking systems was monitored using Sinergy Escot energy monitoring equipment and software. The Escot data-logger can measure power consumption of multiple electrical circuits using clip-on AC current transducers. The logging software records cumulative kilowatt-hour (kWh) readings every 15 minutes. Measurement equipment was calibrated and accurate to ±1% of reading. This equipment allowed for measurement of the following individual components in the dairy: milking robot, vacuum pump, air compressor, milk cooling and water heating.

Experimental measurements

In year one of the study, prior to installation of the AMS and herd of 107 cows were milked in a 20 unit herringbone parlour equipped with automatic cow identification, milk metering technology and automatic cluster removers. This milking machine had two 4 kW vacuum pump motors. Water heating was provided by two 3 kW 300 l electrical water heaters. Milk was pre-cooled using a plate heat exchanger supplied with well water and subsequently cooled in a 10,000 l direct expansion bulk milk tank. Vacuum level was controlled by a standard regulator. Cows were milked twice per day and yielded 3,566 l per cow over the monitoring period.

In years 2 and 3 of the study the spring calving herd (herd size of 63 and 72 cows, respectively) was milked from pasture using a Merlin AMS*. Data presented here pertains to the period from May to October of both years. Cows were milked on average 1.78 times per day in 2011 and 1.87 times per day in 2012. Average milk yield over the period was 3,079 l and 3,388 l per cow over the 26 week periods in 2011 and 2012, respectively. The AMS was washed with hot water 3 times per day during 2011 and twice per day in 2012. Water heating was provided by electrical water heaters. Milk was pre-cooled using a Packo tubular cooler (model TT2) supplied with well water and subsequently cooled in a 5,000 l ice bank tank. The vacuum pump was a vane pump with a 3 kW motor. Vacuum level was controlled by a standard regulator from weeks 1-6 of 2011, while a variable speed drive (VSD) controlled pump with 1.1kW motor was used thereafter. Compressed air was supplied by a 2.2 kW compressor.

Data analysis

Raw data from the electricity monitoring system were exported to spreadsheets, and subsequently used to compute the electricity consumption of individual components as well as total dairy electricity usage. To determine electricity costs of individual items, electricity data was combined with day and night rate pricing tariffs (day tariff was 0.18 €/kWh; night tariff was 0.08 €/kWh from 00:00 to 09:00).

Results and discussion

Energy consumption of the AMS

Total energy use of the AMS was 105.63 Watt-hours per litre of milk produced (Wh/l) during its first lactation (range 68.58 - 178.15 Wh/l) and 84.27 Wh/l in its second lactation (range 52.88 – 113.39 Wh/l). further data on the performance of the milking systems over 3 years is presented in Table 1.

Table 1: Description of main system characteristics over the three year duration of the study

	Conventional 2010	AMS[1] 2011	AMS 2012
Milking frequency (Milkings/cow/day)	2	1.78	1.87
Milk production per cow	3566	3079	3388
Energy consumption (Wh/l)[2]	46.90	105.53	84.27
Energy costs (€ c/l)[3]	0.79	1.36	1.09

[1] AMS = Automatic Milking System
[2] Wh/l = Watt-hour per litre of milk produced
[3] € c/l = Euro cent per litre of milk produced (excludes taxes)

Water heating accounted for the largest portion of energy use (39% and 30% in 2011 and 2012). Reducing hot water wash cycles from 3 times per day to twice per day in 2012 reduced energy consumption by the water heating system by 38% (from 40.77 to 25.44 Wh/l). This requirement is a consistent fixed cost irrespective of the volume of milk produced because wash cycle scheduling is time based. The average TBC results were 18,000 cells/ml across both the 2011 and 2012 milking seasons.

Changing from a standard vacuum regulator controlled vacuum pump system to a VSD vacuum pump in week 6 of the 2011 season reduced vacuum pump energy use by 63% (from 19.19 to 7.09 Wh/l).

The energy consumption of the milk cooling system, air compressor, vacuum pump and robot in 2011 and 2012 are presented in Table 2. Miscellaneous items such as wash pumps and an office consumed 15.53 and 12.66 Wh/l in 2011 and 2012 respectively. When the relevant tariffs were applied, the average cost of electricity was 1.36 Euro cent per litre of milk (c/l) in 2011 (range 0.84 – 2.42 c/l) and 1.09 c/l in 2012 (range 0.68 – 1.58 c/l).

The average AMS running costs of 1.36 c/l (2011) and 1.09 c/l (2012) were high compared to an audit of conventional milking systems (0.43c/l) on 21 commercial dairy farms (May-October 2010) by Upton *et al.* (2011). This may be due to either reduced milk output from the AMS during the start-up years, (when milk yield is expected to be reduced by 10-15% (Wade *et al,* 2004)) and/or under utilization of the AMS. Sixty three and seventy two cows were milked in this grazing based study in the first two years of operation, whereas the possibility to extend capacity to 112 is considered achievable (Jago *et al.,* 2006).

Energy consumption of the conventional milking system

Total energy use in the conventional 20 point herringbone milking plant from 2010 was 46.9 Wh/l (range 34.38 to 65.00 Wh/l). The water heating system was the largest energy user (29% of total). Other major energy users were the vacuum pumps (26%), milk cooling system (25%) and lighting (13%). There was no air compressor used during milking on the conventional system. This is a key difference between the two systems as the energy consumption of the air compressor alone was 17.13 Wh/l on the AMS in 2012. Average energy costs were 0.79 c/l (range 0.55 – 1.02 c/l). The average costs are higher than the average figures presented by Upton *et al.* (2011) (0.43 c/l) from a study of 21 commercial farms with an average herd size of 106 cows.

However the cows milked in the convention milking parlour in year one of this study had extended milking times due different experimental treatments in the research centre farm, which may have lead to higher energy consumption.

Table 2: Breakdown of electricity consumption per litre of milk produced including cost of electrical energy consumed during three 26 week periods i) May-October 2010 with a conventional herringbone milking system, ii) May-October 2011, 1st lactation with an AMS, iii) May-Oct 2012, 2nd lactation using an AMS

	Conventional 2010 (Wh/l)[1]	AMS[2] year 1 2011 (Wh/l)	AMS year 2 2012 (Wh/l)
Vacuum pump	12.38	11.54	7.41
Cooling	11.54	15.39	16.75
Lighting	6.26	2.74	2.23
Air Compressor	na[3]	16.41	17.13
Water Heating	13.65	40.77	25.44
Other	3.07	15.53	12.66
Robot	Na	3.25	2.64
Total	46.90	105.63	84.27

[1] Wh/l = Watt-hour per litre of milk produced
[2] AMS = Automatic Milking System
[3] na = Not applicable

Conclusion

Average electricity consumption of the AMS tested with 63 and 72 cows in 2011 and 2012 milking seasons were 105.63 and 84.27 Wh/l respectively. These figures were higher than the conventional herringbone milking system used on this farm in 2010 prior to the AMS installation. Largest energy consuming processes associated with milk harvesting in the AMS were heating water, compressing air and cooling milk. It is likely that the energy use of the AMS will reduce further as cows become familiar with the AMS and optimum herd size/milk output for the AMS is reached. The suitability of a heat recovery system (designed to recover waste energy from the milk cooling system) and cold detergent wash cycles, in place of hot water wash cycles, will be investigated in 2013 to moderate running costs further.

* Merlin AMS supplied by Fullwood Ltd

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Gold standards concepts for automatic lameness assessment systems in dairy cows

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Abstract

Lameness is an important welfare problem in modern dairy farms. In order to support lameness control in dairy farms, several concepts to develop a reliable automatic lameness assessment systems (ALAS) have been undertaken. Golden standards methods used for ALAS development are discussed based on a literature review. 16 out of 18 articles related with automatic lameness assessment systems used locomotion scores as gold standard. Main advantages of locomotion scores as gold standard lie on their practical application. Locomotion scores are easy and cheap to use in practice. Disadvantages of locomotion scores as gold standard are related with validity and repeatability of the method. Locomotion scores as tool for pain and hoof lesions (potential source of pain) seems limited because, cows seems to present an important tolerance to pain and locomotion is also impaired by the practical conditions in which it is assessed. Repeatability for locomotion assessment showed a large variation between and within observers. The main factor in the variation of repeatability seems to be the subjectivity associated to locomotion scores. Poor validity and repeatability hinders the interpretation of what is finally being assessed by LSs and ultimately by ALAS. Hoof and painful lesions are also used as gold standard for ALAS development. As LS diagnosis of hoof and painful lesions are also subjective and may present poor repeatability. In conclusion, currently there is not an optimal gold standard for the development of ALAS.