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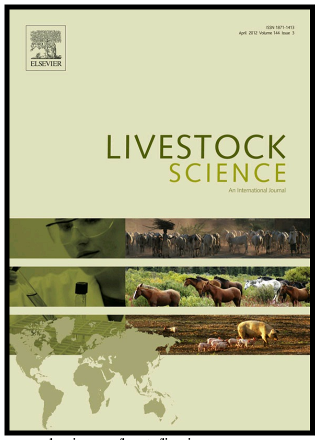

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The effect of dairy cow breed on milk production, cow traffic and milking characteristics in a pasture-based automatic milking system

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ABSTRACT

Despite the increasing frequency of integrated automatic milking (**AM**) and pasture-based systems, there is limited knowledge available on the suitability of different dairy cow breeds to these systems. Thus, the objective of this experiment was to establish the performance of three breeds in a pasture-based AM system with respect to milk production, cow traffic and milking characteristics. The breeds examined were Holstein Friesian (**HF**), Jersey x HF

(**JEX**) and Norwegian Red x HF (**NRX**), all of which have been previously identified as being compatible with conventional milking pasture-based systems. The experiment was conducted in mid-lactation and variables measured included milking frequency, -interval, -outcome and -characteristics, milk yield/milking and per day, wait time/visit and per day, return time/visit and the daily distribution of milking events. Data were statistically analysed using least squares means mixed procedure models, while the proportion of different milking events were analysed using the logistics procedure. While there were no significant differences between breeds for milking frequency, or milk production, significant differences did exist for proportion of successful and failed milkings events, with NRX cows recording the highest and lowest proportions, respectively. JEX also recorded a significantly shorter dead time/quarter at 17.6 seconds/milking compared to the HF and NRX breeds at 28.5 and 27.7 seconds/milking, respectively. Significant differences also existed with regard to cow traffic, with the NRX breed returning from pasture more quickly and waiting a shorter time both per visit and per day in the pre-milking yard. The distribution of milking events differed between the breeds examined, with the JEX cows recording less milkings in the hour after the pre-selection gate changes of 0000 h and 1600 h. JEX also recorded a significantly greater proportion of milkings than the NRX and HF cows during the hours at which the lowest proportion of total milking events were recorded (0400 h – 0600 h). For the optimisation of the AM system it is important to have an even distribution of milkings throughout the day. Based on the evidence from the current experiment, this may be best achieved by a mixed breed herd rather than a single breed herd. However, the performance of the examined breeds should also be analysed in the context of the whole AM farm system, over an entire lactation, taking into consideration the range of variables that contribute to a profitable farm system.

Keywords: milking frequency, milking distribution, Holstein-Friesian, Norwegian Red, Jersey

INTRODUCTION

Automatic milking (**AM**) systems are becoming increasingly popular, with approximately 25,000 farms worldwide operating this type of milking system (Harms and Bruckmaier, 2016). Furthermore, the combination of AM and grazing, using initially two-way grazing (Jago et al., 2004) and subsequently three-way grazing (Lyons et al., 2013), has allowed the adoption of AM in countries such as Australia, New Zealand and Ireland where grazing plays a key role in milk production. It is well documented that seasonal calving systems, where grazed grass forms the main component of the dairy cow's diet, have a comparative advantage in reducing costs and increasing overall farm profitability (Dillon et al., 2005). Thus, it is vital in pasture-based farms that do adopt AM, that the utilisation and conversion of pasture into high value milk constituents is maximised. In AM, this conversion to milk is very much influenced by the suitability of the cow to (i) grazing and (ii) uneven milking intervals; both of which are influenced by cow breed.

The widespread use of Holstein-Friesian (**HF**) genetics to increase milk production potential (Harris and Kolver, 2001, Evans et al., 2006) has ultimately compromised the fertility of the global dairy herd (Harris and Kolver, 2001, Norman et al., 2009), which is the cornerstone of all seasonal calving pasture-based production systems. Additionally, Kennedy et al. (2003) established that HF cows may not fulfil their genetic potential in pasture-based systems, as when these cows are on diets consisting of pasture only, they cannot consume sufficient energy to meet their requirements (Kolver and Muller, 1998). Such studies led to a focus on crossbreeding in order to establish a robust cow capable of meeting her energy requirements from a predominantly pasture-based diet (Buckley et al., 2005). Subsequently, Walsh et al.

(2007) established the Norwegian Red breed as a highly suitable breed for crossing with the HF in pasture-based systems. Begley (2008) showed that Norwegian Red x HF (**NRX**) cows had a similar production potential and significantly improved reproductive performance and udder health compared with the HF, resulting in an increased profit of €143 per lactation compared to the HF.

Numerous international studies have examined the benefits of the subsequent Jersey x Holstein Friesian (**JEX**) offspring. In an Irish context, Prendiville et al. (2009) concluded that the JEX was an animal highly suited to grazing systems due to their high intake capacity at pasture, combined with the added benefit of improved production and feed efficiency. Furthermore, Coffey et al. (2016) also established that the JEX was worth an additional €162 per lactation over the HF, due to superior milk production and reproductive performance. These results concur with those found on a global basis, showing JEX to have improved production (Penno, 1998), fertility (Auldist et al., 2007, Heins et al., 2008), intake capacity (Goddard and Grainger, 2004) and subsequently, improved profitability (Lopez-Villalobos et al., 2000). Furthermore, Clark et al. (2006) showed that milk yield of Jersey cows was not reduced with once daily milking to the same extent as that of HF. Additionally, the yield of milk solids from Jersey cows on once daily milking was maintained to a greater extent than that of HF cows. This could be a significant attribute in a pasture-based AM system, where the optimum AM system utilisation (daily proportion of time the robot(s) are in operation) may be best achieved with a low milking frequency/cow and a high AM:cow ratio (Woolford et al., 2004).

However, little is known about the performance of these breeds in pasture-based AM systems, in particular with regard to cow traffic and ultimately how this will affect robot utilisation and efficiency, as highlighted by John et al. (2016). As voluntary cow traffic (the voluntary movement of cows around a farm) is the foundation on which successful AM operates, it is essential to develop an understanding on the suitability of different breeds to AM pasture-based systems. Thus, the objective of this study was to evaluate the HF, the NRX and the JEX breeds in a pasture-based automatic milking system, with regard to milk production and cow traffic.

MATERIALS AND METHODS

Animal and experimental description

The experiment was conducted at the Dairygold Research Farm, Animal and Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland (50°07′N, 8°16′W), between April 20th and August 30th, 2015. Moorepark's soil type is described as a free-draining brown earth soil of sandy loam to loam texture. The farm-let area was a permanent grassland site, of predominately perennial ryegrass sward (*Lolium perenne* L.).

Fifty spring-calving dairy cows (17 HF, 16 JEX and 17 NRX) were selected from the Teagasc Moorepark AM herd, consisting of 80 cows. Thirty-five cows were multiparous and the remaining 15 were primiparous. Breed groups were balanced for parity, days in milk (**DIM**), economic breeding index (**EBI**) and concentrate consumed per cow (kg) from calving until start of experiment. The characteristics of the breed groups were as follows: HF cows: parity 2.8 ± 1.1 (mean ± SD), DIM 51 ± 23, EBI 195 ± 24 and concentrate consumed 138 ± 88 kg/cow; JEX cows: parity 2.8 ± 1.2, DIM 58 ± 17, EBI 189 ±27 and concentrate consumed 154 ± 64 kg/cow; and NRX cows: parity 2.8 ± 1.4, DIM 53 ± 19, EBI 189 ± 30 and concentrate consumed 154 ± 74 kg/cow. The non-trial cows milking on the AM unit were spring calving HF cows with the following characteristics: parity 3.5 ± 0.5, DIM 46 ± 22, EBI 200 ±41 and concentrate consumed 191 ± 94 kg/cow.

After calving, all cows were offered grazed pasture and 3 kg concentrate/cow per day until April 1st, after which cows were offered grazed pasture and 0.5kg concentrate/cow per day until the end of the experimental period. Cows were allocated 85% of their daily concentrate allowance in the first milking of the day, with the remainder offered in the subsequent milking. Concentrates were dispensed at a rate of 4 grams/minute. All cows were calved a minimum of 10 days prior to trial start, were familiar to the farm layout and were well conditioned to milking and trafficking in the pasture-based AM system. The experiment consisted of a seven-day adjustment period, a seven-day control period and a 17 week data collection period. Cows were milked using a Fullwood Merlin 525 AM unit (Fullwood Ltd, Ellesmere, United Kingdom). Given the overall high ratio of cows:AM unit (80:1), all cows (including non-trial cows) were allowed a milking permission of two times per day (minimum milking interval of 12-h) using the Crystal Software (Crystal 0.44, Fullwood Fusion, Willem Alexanderweg 83, 3945 CH Cothen, The Netherlands). Therefore, if a cow trafficked to the milking yard within 12-h of her previous milking event she was denied access to the robot by a pre-selection drafting gate. The cow was then directed to a post-selection gate where she was sent back to pasture. Washing of the AM unit took place twice daily, at midnight and midday for approximately 10 minutes on each occasion.

Grazing Management

Breed groups grazed as one herd of 80 cows (50 trial cows and 30 non-trial cows), without any physical separation. The experimental grazing area consisted of 25.2 ha divided evenly into three grazing blocks (A, B and C), with 15 individual paddocks in each grazing section separated by permanent fences. Cows were allowed access to each grazing section for 8 hours; block A from 0000 h – 0800 h, block B from 0800 h – 1600 h and block C from 1600 h – 0000 h. Once access to a grazing section had closed no further cows were allowed into that section; however, cows that were already present in that grazing section were allowed to remain there until leaving that section voluntarily. Cows who did not leave the paddock voluntarily were subsequently fetched prior to the opening of the next grazing allocation. The farm was walked weekly to assess farm pasture cover through visual estimation. Paddocks that were deemed to have a pasture cover greater than target were removed from the grazing rotation. Cows were strip-grazed within each paddock, with cows receiving a new strip in each section over each 24 hour period. The size of the area allocated to the herd was determined by calculating the pre-grazing herbage mass. The pre-grazing herbage mass (>4 cm) was determined twice weekly by cutting two strips of grass per paddock (1.2 m × 10 m) using an Etesia mower (Etesia UK Ltd., Warwick, UK). Ten measurements of compressed sward height were taken pre- and post-cutting using a rising plate meter (diameter 355 mm; Jenquip, Feilding, New Zealand). All mown grass from each cut was weighed and then a sample was collected. A subsample of 0.1 kg was dried at 90°C for 16 hours for DM estimation. Pre- and post-grazing sward height was assessed daily using a Jenquip rising plate meter. Pre- and post-grazing sward heights were measured by taking 30 measurements/ grass allocation per day.

Chemical Analysis

A composite sample of grass was formed from the two strips of grass cut in each paddock prior to grazing. These samples were frozen at -20°C and at the end of each grazing rotation the samples were bulked by bowl chopping. Samples were subsequently freeze dried for 48 hours, milled though a 1mm sieve and stored for chemical analysis. They were subsequently analysed for DM, ash, acid detergent fibre (**ADF**), neutral detergent fibre (**NDF**; ANKOM™ technology, Macedon, NY, USA; (Van Soest et al., 1991)), crude protein (**CP**; Leco FP-428; Leco Australia Pty Ltd., Baulkham Hills, New South Wales, Australia) and organic matter digestibility (**OMD**; Fibertec™ Systems, Foss, Ballymount, Dublin 12, Ireland; (Morgan et al., 1989)). The concentrate offered was sampled each week and analysed using near infrared reflectance spectroscopy (**NIR**; Foss-NIR System DK, Hillerød, Denmark) for CP, NDF, ash and crude fibre..

Data Description

Cows were fitted with a leg mounted radio transponder identification device (Afitag, Afimilk, Kibbutz Afikim, 1514800, Israel) that allowed automatic identification at the pre- and post-selection gates and in the milking unit. Thus, data from both the selection gates and the AM unit were recorded electronically. Data recorded by the AM system included cow number, milk yield/milking and per day (kg), milking frequency/day, the daily distribution of milkings, milking interval (hours), average dead time/quarter (seconds; recorded from milking cup attachment until the commencement of milk flow), milking duration (minutes/cow; recorded from the commencement of milk flow until the end of milk flow), average milk flow rate (kg/minute) and concentrate consumed/cow (kg/cow). At the conclusion of a milking event, that milking event was assigned one of three possible outcomes; successful, yield carry over (**YCO**) or failure, according to the actual yield of milk produced relative to the expected yield. A milking was deemed successful when >80% of the expected yield was harvested, a YCO was defined as when >20% and <80% of expected yield was harvested, while a failed milking occurred when <20% of expected yield was harvested. After a failed milking, the cow was returned to the milking yard for another attempt at milking. A YCO milking also resulted in an earlier admission (than permitted by the milking permission setting) of that cow to the milking robot for the subsequent milking, with the timing of re-entry determined by the proportion of milk harvested in the previous milking. All data concerning milking parameters excluded failed milkings since these cows were automatically returned to the pre-milking waiting yard for another milking. The recording of the passing of each individual cow at the selection gates by Logview software (Fullwood Ltd, Ellesmere, United Kingdom) allowed for the calculation of cow traffic variables. These included return time (time, in hours, elapsed from when a cow exited the post- selection gate until she returned to the pre-selection gate) and wait time (time, in hours, elapsed from when a cow entered the pre-milking yard until she entered into the AM unit). The variable return time, represented the average of return times associated with individual visits to the milking yard, whereas the variable wait time represented the average of wait times for individual visits. Wait times were also summed for each 24 hour period to give a daily wait time value. Activity minutes were measured using the leg mounted radio transponder which also acted as a pedometer. The cows were fetched from pasture as one herd on three occasions during the experiment to allow for annual vaccination and implementation of herd health strategies. Data from each of these days and the subsequent 48 hours after treatment were removed from the dataset to allow the cows to re-establish a voluntary routine. Cows had their bodyweight recorded on each of the three occasions using a portable weighing scales and the Winweigh software package (Tru-Test Ltd., Auckland, New Zealand).

Statistical Analysis

Data were statistically analysed using least squares means ANOVA using mixed procedure analysis (PROC MIXED) in SAS v9.3 (SAS Institute Inc., Cary, NC, USA). Cow was included as the random effect and therefore weekly measurement was treated as the repeated measure. Data from the control week was included as the covariate for each dependent variable. Models for variables such as milking frequency, milking interval, milk yield/milking and per day, milking duration/milking and per day, milk flow rate, average quarter dead time, activity/day and return time/visit included the effects for breed, pre-experimental concentrate consumption, parity, DIM and interactions, while models for wait time/visit and per day also included cow bodyweight to account for the effect that any variation in bodyweight between the breeds may have on waiting time. The covariance structure of models were tested and the selection among autoregressive (1), heterogeneous autoregressive (1), compound symmetry, heterogeneous compound symmetry and unstructured covariance structures were determined based on the lowest Akaike's Information Criterion and Bayesian Information Criterion (Littell et al., 2006). The Kenward-Rogers method was used for the calculation of degrees of freedom for all mixed models. Significance was set at 5% (P <0.05), with non-significant effects removed from the models by backward elimination. Significance was examined by *post hoc* analysis of means using a Tukey-Kramer test. The milking event outcome proportions were pooled by treatment and analysed using the logistics procedure (PROC LOGISTIC) of SAS. The daily distribution of milking events were analysed using frequency procedure (PROC FREQ) of SAS. Significance for $\chi 2$ test were used to test between breed groups in relative frequency of milkings at any particular hour. Where significance was determined by the omnibus test, a multinomial logistics regression was performed using the logistics procedure in SAS, to examine the relationships between the breeds.

RESULTS

Grazing and dietary characteristics

Results of the grazing characteristics and grass chemical analyse for the grazed pasture during the experiment are outlined in Table 1. Total grass allocation was 20.9 kg DM/cow, with 6.8, 6.9 and 7.2 kg DM/cow allocated in grazing blocks A, B and C, respectively. The average distance that cows had to walk from the yard to a paddock was 325 metres (range 25-650 metres). Total daily concentrate consumption/cow was 0.48, 0.48 and 0.46 ± 0.03 kg/cow for the HF, NRX and JEX breeds, respectively. Mean concentrate chemical composition was crude protein (**CP**) 163g/kg of dry matter (**DM**); Crude Fibre 136g/kg of DM; Ash 54g/kg of DM; and neutral detergent fibre (**NDF**) 351g/kg of DM.

Milking frequency, interval and outcome and milk production

Milking parameters such as milking frequency, milking interval and milking outcome are outlined in Table 2. While HF and NRX had a numerical greater milking frequency and shorter milking intervals than JEX, there was no significant effect of breed on either of these parameters. When the milking event statuses of each breed was analysed as a proportion of the total milking events for that breed, significant differences (P <0.001) were observed for the proportion of successful milking events, with the NRX cows recording a significantly greater proportion, followed by the HF and JEX. Despite this, there was no significant difference between breeds for YCO milkings. However, the differences in the proportion of successful milking events impacted on the number of failed milking events, with a significantly greater proportion of the JEX milking events (P <0.001) recorded as failed milking events (6.1%). This is in comparison to NRX and HF breeds which had the lowest (0.9%) and intermediate (2.8%) proportion of failed milking events, respectively, with these breeds also differing significantly (P <0.001). Milk production results are also shown in Table 2. While there was no significant difference between the breeds for milk production, the difference between HF and JEX approached significance.

Cow traffic and activity

The effect of breed on cow traffic and activity data is outlined in Table 3. There was a significant difference in return time/visit between the breeds (*P* <0.05), with NRX cows returning from pasture to the milking yard 42 minutes sooner than the JEX cows. There was also a significant difference (*P* <0.05) between the breeds for wait time/visit and per day. NRX cows had a significantly shorter waiting time/visit and per day in the pre-milking yard of 0.9 and 1.3h, respectively, compared with the HF cows of 1.3, 1.7h and JEX cows of 1.5 and 1.9h, respectively. A significant difference (*P* <0.05) was also observed between breeds for daily activity measurements. JEX cows had significantly greater activity levels than HF cows, with the former recording 84 minutes more activity daily.

Milking distribution

Figure 1(a) shows the overall pattern and distribution of milking events of the cows being examined in the experiment, while the effect of breed on the hourly distribution of milking events is outlined in Figure 1(b). There was a significant difference in the proportion of milking events in at least one pairwise comparison between the breeds at 12 out of the 24 time points examined. All three breeds differed significantly (*P* <0.001) at two of those time points, namely, 7 and 8 with JEX having the greatest proportion of milkings at both time points (51 and 48%, respectively), followed by NRX (34 and 32%, respectively) with HF having the lowest proportion of the milking events (16 and 20%, respectively). Both HF and NRX had significantly greater (*P* <0.001) proportions of milking events than JEX at time points 0, 1, 12, 17 and 18 (*P* <0.01). Conversely, JEX and NRX had significantly greater proportions of milkings than HF at time point 6 (*P* <0.001). Additionally, JEX had significantly more milkings than NRX and HF at time points 4 (*P* <0.05) and 21 (*P* <0.05), respectively, and significantly less milkings than NRX at time point 16 (*P* <0.01).

Milking characteristics

Results of the milking characteristics such as milking duration/milking and per day, milk flow rate and average dead time/quarter are presented in Table 4. There was no significant effect of breed on milking duration/milking and per day and milk flow rate. While the aforementioned milking characteristics were not significantly different between breeds, there was a significant effect (P <0.05) of breed for average dead time/quarter. The JEX cows had 37% less dead time, that is time until milk let-down, than HF cows, who had the longest dead time of 28.5 seconds.

DISCUSSION

While Nieman et al. (2015) previously reported the performance of different strains of the HF breed in a pasture-based AM system, as far as we are aware, the current experiment represents the first analysis conducted using the controlled settings of a research herd to compare the effect of dairy cow breed on milk production, milking characteristics and cow traffic parameters in a pasture-based AM system. While, Clark et al. (2014) examined the cow traffic performance of HF and Illawarra breeds, that study was conducted retrospectively from research herd data and had varying numbers of cows within each breed. Furthermore, the current component study not only encompasses breeds such as the HF, which are common to global pasture-based systems, but also crossbreds which have been identified as being particularly suited to the efficient conversion of pasture to high value milk, such as the JEX (Goddard and Grainger, 2004, Prendiville et al., 2009, Coffey et al., 2016) and NRX (Begley, 2008, Walsh et al., 2008, Begley et al., 2009a).

The effect of breed on milk production, milking frequency, interval and outcome

The results of the current experiment with regard to milk yield are largely in agreement with those from previous experiments. Walsh et al. (2008) and Begley et al. (2009b) compared purebred Norwegian Red and NRX, respectively, to the HF. Both studies indicated that the respective breeds had similar yields of milk volume to HF cows. When examining the performance of the JEX cows in the current experiment, the trends were similar to those observed in previous studies (Auldist et al., 2007, Prendiville et al., 2011, Vance et al., 2013), with JEX cows having a lower milk volume than HF, although not significant in the current experiment.

Milking frequency did not differ significantly between breeds. However, the JEX cows did record a significantly lower and greater proportion of successful and failed milking events, respectively, compared to the other breeds. Further examination of the raw data showed that the JEX cows had a far greater variation in milking interval than the HF and NRX breeds. They had a greater proportion of milkings with intervals <12 hours (due to failed and YCO milkings allowing cows access to the AM unit sooner than normally permitted under the selected milking permission settings) and a greater proportion of milkings with intervals >20 hours. This greater variation in milking interval creates the potential for large changes in udder shape between milkings, resulting in greater difficulty achieving successful cup attachment (Jago et al., 2007). While the HF breed were intermediate between the JEX and NRX, they also achieved significantly lower successful and significantly greater failed milkings compared to the NRX cows. However, the differences recorded (2%) were not as pronounced as those between the JEX and NRX (5%); thus, HF performance was more comparable to NRX than JEX.

The effect of breed on cow traffic and milking distribution

While the cows in the current experiment were not ranked based on social dominance, as was the case for Jago et al. (2003), that study provides some possible explanations for the trends in cow traffic parameters observed in the current experiment. The NRX cows had the shortest return time, followed by the HF, while the JEX cows had the longest. Jago et al. (2003) observed that when cows have negative experiences on roadways or in milking waiting yards, including encounters with cows of higher social rank within the herd, that this can reduce the motivation of those cows to move from pasture to the AM unit. An experience that could be considered negative in the current experiment may be the significantly longer pre-milking yard waiting time, both per visit and per day for the HF and JEX cows than the NRX cows, thus, resulting in the longer return times than the NRX cows. Longer pre-milking yard waiting times could also have an effect on grazing time with cows waiting the longest, grazing the longest (Jago et al., 2003); however this was not measured in the current experiment. Incidentally, Prendiville et al. (2010a) demonstrated that JEX cows were more intensive grazers than both their parent breeds in a conventional milking system, grazing for 20 minutes longer, with a higher bite rate and grass dry matter intake. However, the grazing dynamic may be very different in an AM system, as cows enter pasture at varying stages of pasture depletion; thus, cows which enter a pasture allocation last, have to graze for longer to achieve the same level of nutritive intake as those that entered the pasture allocation at an early stage (Clark, 2013, John et al., 2015).

Examination of the distribution of milking events across the day indicated a significantly greater proportion of both HF and NRX cows milking immediately following the opening of two out of the three fresh allocations of pasture. This indicated that more cows from those respective breeds entered the fresh pasture allocation before a substantial depletion of it would have taken place. Interestingly, a substantially greater proportion of JEX cows were milked between time points three and eight and considering that the fresh pasture was made available in block A at midnight, milking between these times may indicate the entry of these cows into grazing block A at a time when there was considerably less pasture available than if they were milked earlier. Ketelaar-de Lauwere et al. (1996) reported lower social ranking cows visited the AM unit more frequently during the midnight to 6am period, while Jago et al. (2003) found that more milkings of lowering ranking cows occurred during the late evening period. Based on the findings of those studies, and the distribution of milking events among the breeds in the current experiment, it could be hypothesised that HF and NRX breeds were among the more highly ranked cows in the study, while the JEX cows represented some of the more lowly ranked cows. However, the study of Ketelaar-de Lauwere et al. (1996) was based on an indoor AM system and caution is recommended when drawing comparisons with pasture-based systems. It should also be noted, however, that the 30 non-trial cows milking in the herd were of the HF breed. These may have impacted negatively upon the JEX cows were the above hypothesis to be true.

The significantly reduced number of milkings for JEX cows immediately after the opening of fresh pasture at time points 0, 1 and 17 would indicate that if those cows did traffic to the milking yard anticipating the allocation of fresh pasture at those time points, they were not successful in accessing the AM unit in the presence of the HF and NRX cows, as there may have been a behavioural limitation on the behalf of the JEX cows (Jago et al., 2003). Conversely, at the allocation of fresh pasture at time point 8, the JEX cows had a significantly greater proportion of milkings, both at that time point and at the previous time point (time point seven) than the other two breeds examined. The reasons for this are unclear, and it may be a consequence of the JEX remaining present in grazing block C for an extended duration and, as a result only trafficking from pasture to the milking unit upon sunrise. Additionally, the diurnal grazing pattern of dairy cows (Gregorini, 2012) may have resulted in reduced grazing time for the cows in block A compared with the other blocks, meaning that upon the opening of fresh pasture in block B at time point 8, there was potentially a substantial amount of pasture remaining in the previous allocation, which may have discouraged the cows who trafficked to block A from leaving. However, this remains conjecture, as cows were not either visually or electronically monitored for location or time of entering or exiting pasture.

The effect of breed on milking characteristics

To date, there has been little research carried out on the effect of different breeds on milking characteristics such as milking duration, average milk flow and dead time. Both Arave et al. (1987) and Prendiville et al. (2010b) examined the difference in milking duration/day between HF, Jersey and JEX in a twice daily milking pasture-based CM system over the entire lactation. In line with the current experiment, no differences were found between the HF and JEX for milking duration. Likewise, Walsh et al. (2007) compared the milking characteristics of the HF and purebred Norwegian Red and found them similar in terms of milking duration and milk flow rate. However, it was noteworthy, that while there was no breed effect for average milk flow in the current experiment, the difference is approaching significance (P = 0.10). Dead time/ quarter, or the period to milk let-down, was significantly shorter in the JEX cows than both the HF and NRX cows. This is likely a direct consequence of selection against cows with a requirement for udder stimulation to trigger milk let-down within the Jersey breed (Phillips, 1986), as udder preparation is not regularly practiced as part of the milking routine in New Zealand where there are a large population of Jersey cows (Jago et al., 2006a). Phillips (1986) also demonstrated that when pre-milking stimulation was applied, both Jersey and JEX cows showed a greater response than the HF breed.

Additional considerations

As outlined earlier, the current experiment was a component study during the mid-lactation period of a seasonal calving herd, focusing predominantly on the milking and cow traffic performance of the respective breeds. Thus, it is important to consider these results in the context of a whole farm system, where key performance indicators not considered in this experiment such as milk solids production, fertility, survivability and efficient conversion of feed to high value milk are vital aspects of a profitable milk production system. Given the reduced profitability of AM compared with CM in low input pasture-based systems (Jago et al., 2006b, Shortall et al., 2016), increasing grass intake by the cow and subsequent milk solids harvested per robot will be of particular importance with an AM system. Woolford et al. (2004) suggested that this should be achieved with up to 100 cows/robot. However, in a seasonal calving system the robot will be the limiting factor in peak lactation, with potential for extended milking intervals. However, Hogeveen et al. (2001) and Lyons et al. (2013) have both highlighted that milk production remains steady for up to a 16 hour milking interval, but declines subsequently. Thus, a robust cow capable of sustaining periods of long milking intervals is required for AM in a pasture-based system. Similarly, for optimisation of the AM system it is important to have an even distribution of milkings throughout the day. Based on the evidence from the current experiment, this may be best achieved by a mixed breed herd rather than a single breed herd.

CONCLUSION

The objective of this study was to examine the effect of cow breed in a mixed breed AM dairy herd on milk production, cow traffic and milking characteristics. While breeds did not differ significantly for milking frequencies, differences existed within the cow traffic parameters measured. The NRX cows had the shortest return time and pre-milking yard waiting time while the JEX cows had greater activity levels. The distribution of milking events could imply that the HF and NRX cows were visiting the yard in anticipation of the allocation of fresh pasture. These data indicated that the NRX cows trafficked most efficiently through the system and could be a more dominant breed of cow. However, the performance of the breeds should be analysed in the context of the whole AM farm system over an entire lactation, both as a mixed and single breed herds, taking into consideration the range of variables that contribute to a profitable farm system.

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Table 1. Grazing characteristics and grass quality combined for each of the three grazing sections

		SD[1]
Pre-grazing herbage mass >4 cm (kg DM/ha)	1646	263.5
Pre-grazing sward height (cm)	11.7	1.41
Daily herbage allowance (kg DM/cow)	20.9	4.66
Post-grazing sward height (cm)	5.6	0.64
Crude protein (g/kg DM)	196	35.6
Acid detergent fibre (g/kg DM)	266	23.6
Neutral detergent fibre (g/kg DM)	405	39.6
Organic matter digestibility (g/kg DM)	828	29.2
Ash (g/kg DM)	130	25.8

[1]SD = Standard Deviation

Table 2. The effect of breed on milking frequency, milking interval, and milk yield.

	Breed				
	HF[1]	NRX[2]	JEX[3]	SEM[4]	*P*-value
Daily milking frequency/cow	1.4	1.4	1.3	0.03	0.72
Milking interval/cow (hours)	16.1	16.2	16.4	0.51	0.94
% successful milking events	90.0[a]	91.8[b]	86.1[c]	2.3	<0.001
% YCO[5] milking events	7.2	7.3	7.8	1.4	0.68
% failed milking events	2.8[a]	0.9[b]	6.1[c]	0.9	<0.001
Milk yield/day (kg/cow)	18.7	17.8	17.1	0.70	0.32
Milk yield/milking (kg/cow)	13.9	13.2	12.7	0.50	0.19

[1]HF = Holstein-Friesian
[2]NRX = Norwegian Red x Holstein-Friesian
[3]JEX = Jersey x Holstein Friesian
[4]SEM = Standard error of the mean
[5]YCO = Yield carry over
[a-c]Means within a row with different superscripts differ (*P* <0.05)

Table 3. Effect of breed on return time, wait time and activity in a pasture-based automatic milking system

	Breed				
	HF[1]	NRX[2]	JEX[3]	SEM[4]	*P*-value
Return time/visit (hours/cow)	7.3[ab]	7.0[b]	7.7[a]	0.33	<0.05
Wait time/visit (hours/cow)	1.3[a]	0.9[b]	1.5[a]	0.14	<0.05
Wait time/day (hours/cow)	1.7[a]	1.3[b]	1.9[a]	0.14	<0.05
Activity/day (minutes/cow)	642[a]	666[ab]	726[b]	21.6	<0.05

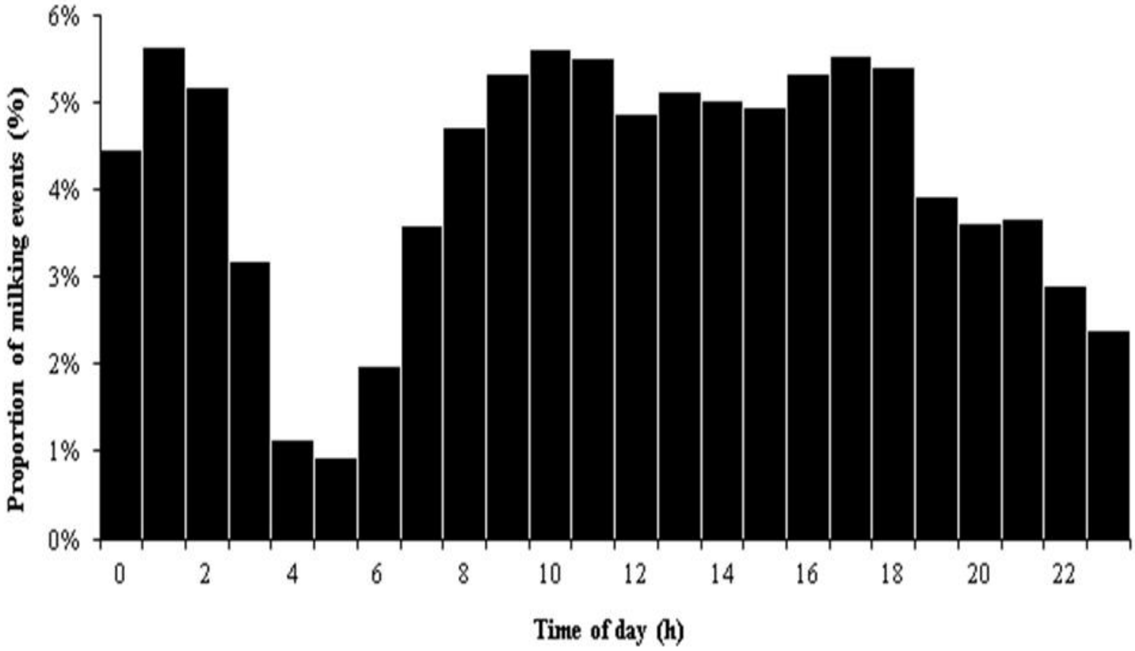
[1]HF = Holstein-Friesian
[2]NRX = Norwegian Red x Holstein-Friesian
[3]JEX = Jersey x Holstein Friesian
[4]SEM = Standard error of the mean
[a-c]Means within a row with different superscripts differ (P <0.05)

Table 4. Effect of breed on milking characteristics in a pasture-based automatic milking system

	Breed				
	HF[1]	NRX[2]	JEX[3]	SEM[4]	*P*-value
Milking duration/milking (minutes/cow)	8.3	8.1	8.6	0.19	0.21
Milking duration/day (minutes/cow)	11.4	10.9	11.5	0.32	0.46
Average milk flow rate (kg/minute)	1.69	1.71	1.53	0.060	0.10
Dead time/quarter (seconds)	28.5[a]	27.7[a]	17.6[b]	2.18	<0.01

[1]HF = Holstein-Friesian
[2]NRX = Norwegian Red x Holstein-Friesian
[3]JEX = Jersey x Holstein Friesian
[4]SEM = Standard error of the mean
[a-c]Means within a row with different superscripts differ (P <0.05)

(a)


6%
5%
4%
3%
2%
1%
0%
Proportion of milking events (%)
0
2
4
6
8
10
12
14
16
18
20
22
Time of day (h)

(b)

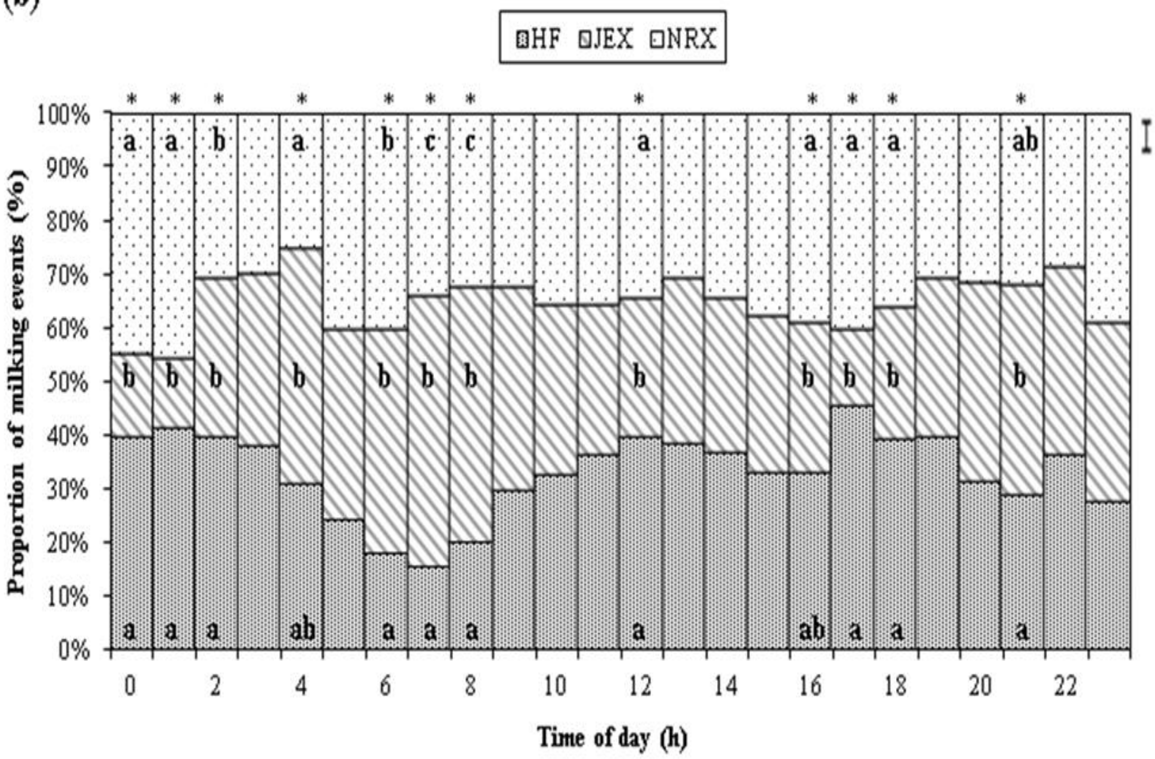

HF
JEX
NRX
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of milking events (%)
0
2
4
6
8
10
12
14
16
18
20
22
Time of day (h)

Figure 1. (a) The combined total number of milkings for all cow breeds, represented as an hourly proportion of the total. The time below each bar represents the h that the milking occurred (i.e. bar 10 represents the milking events that occurred between 1000 h - 1100 h).

(b) The effect of cow breed (HF: Holstein Friesian; JEX: Jersey x Holstein Friesian; NRX: Norwegian Red x Holstein Friesian) on the average hourly distribution of milkings (milkings/breed as a percentage of total milkings at each time point). The time below each bar represents the h that the milkings occurred (i.e. bar 10 represents the milking events that occurred between 1000 h - 1100 h). Hours with significantly different throughput between breeds (P <0.05) are identified accordingly (*). The vertical bar represents the average standard error of the difference.

HIGHLIGHTS

- No differences observed between breeds for milking frequency or interval.
- Norwegian Red x HF (NRX) had the shortest return time from pasture.
- NRX recorded the shortest time waiting in the pre-milking yard.
- Holstein Friesian (HF) and NRX cows trafficked to the yard in anticipation of the allocation of fresh pasture.
- AM optimisation may be best achieved by a mixed breed herd rather than a single breed herd.