SEVENTH FRAMEWORK PROGRAMME

AUTOGRASSMILK

DELIVERABLE 1.2

Grant Agreement number: **FP7-SME-2012-314879**

Project acronym: **AUTOGRASSMILK**

Project title: INNOVATIVE AND SUSTAINABLE SYSTEMS COMBINING AUTOMATIC MILKING AND PRECISION GRAZING

Funding Scheme: **Research for the benefit of SME associations**

Deliverable Number: D 1.2

Deliverable Name: **Optimizing pasture proportion in cow diet in association with Automatic Milking – Specific needs of different cow breed/ type in relation to grazing and AM**

DELIVERABLE 1.2

Optimizing pasture proportion in cow diet in association with Automatic Milking – Specific needs of different cow breed/type in relation to grazing and AM

November 2015

Authors:

Ireland: Bernadette O'Brien and Cathriona Foley

Sweden: Eva Spörndly and Haldis Kismul

Authors, Institutes and e-mail addresses:

Ireland: Dr. Bernadette O'Brien, Senior Research Officer and Dr. Cathriona Foley Livestock Systems Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co.Cork, Ireland.

E-mail: Bernadette.obrien@teagasc.ie and Cathriona.foley@teagasc.ie

Sweden: Eva Spörndly and Haldis Kismul Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala,

E-mail: eva.sporndly@slu.se

Foreword

The underlying research that forms the basis for defining the specific needs of different cow breed/type in relation to grazing and automatic milking (AM) presented in this report has been performed as a part of the EU project FP7-SME-2012-314879, with project name/acronym AUTOGRASSMILK. This EU project is for SME Associations and in this case the SME Associations are organizations that in various ways represent farmers in the partner countries. The project aim has been to develop and implement sustainable farming systems that integrate the grazing of dairy cows with automatic milking in different regions in Europe.

Automatic milking (AM) has increased rapidly in many European countries during the last decades and an increasing proportion of the milk produced comes from AM systems. Grazing is advantageous for economical and animal welfare reasons but farmers generally find it difficult to combine grazing with AM. If solutions can be found there are both economical and animal welfare benefits to be achieved. Therefore, this project has aimed at finding useful solutions which can be implemented to organize management on farms with AM during the grazing season. The objective has been to facilitate grazing on farms with AM in an economic, animal friendly and rational way.

The results from this deliverable are largely based on research performed within this EU project but information based on other relevant research in the partner countries has also been included for the benefit of farmers with AM who are the main target of this research. Within this work package, research performed within one identified task has contributed to this deliverable 1.2:

Task 1.3 Optimum cow breed/ type for an integrated grazing and AM milk production system.

The results presented in this report are based on two different production systems in Ireland and Sweden and represent two different production conditions. In Ireland there were pasture-based extensive production conditions aiming at high proportions of pasture in the diet with low feed costs and in Sweden there were intensive production systems with only small amounts of pasture in the diet, aiming at high milk yield per cow.

The results for Ireland and Sweden in this deliverable will be presented in the following sections. These will be presented in the order of Ireland first whose production system is characterized by a high proportion of pasture in the diet and with Sweden second where, with the exception of organic farms, the proportion pasture in the diet is fairly low and many AM-farms offer the cows pasture only to provide exercise and recreation for the cows.

As the production systems represented in this deliverable represent two sides of the spectrum in terms of grazed grass in the diet and cow breeds specific to each county it is envisioned that these results can be useful for farmers in many countries, including countries that have not been part of the AUTOGRASSMILK project.

Table of contents

Page

Ireland – Pasture Based System

Background

Summary production system

Over a ten year period between 2005 and 2014, the number of farms decreased from 26,800 to 17,500, the total dairy cow numbers increased from 995,800 to 1,127,700, the average herd size increased from 41 to 64 cows per farm, cow production per year increased from 4,464 to 5,200L (Teagasc (www.teagasc.ie/publications/2015/3541/End_of_the_Quota_Era_final.pdf & www.teagasc.ie/publications/2011/1054/Pat_Dillon.pdf) & Central Statistics Office). The national milk production, as quantified by that taken in by processors, increased from 4.9 billion litres in 2005 to 5.7 billion litres in 2014. Additionally, in 2014, the total milk output (incl. imports) was estimated at 6.1 billion litres, 480 million litres was consumed as liquid milk, there were 166,000 tonnes of butter, 71,000 tonnes of skim milk powder and 215,000 tonnes of cheese produced (Central Statistics Office). In 2014, total dairy and ingredients exports increased by an estimated 15% to €3.06 billion. Despite having less than 1% of global dairy production, Ireland supplies 10% of the global infant formula (Board Bia).

Ireland's land area is 6.8 million ha and in 2013 66% of this area was used for agriculture (Agricultural Area Utilised, AAU). Within the AAU 81% was grassland (excluding rough grazing), 11% was rough grazing and 8% was total crops, fruit and horticulture (Central Statistics Office). The area of pasture dedicated to Irish dairy farming is estimated to be in the region of 1 million ha, of which 650,000 ha are used directly for milk production, with the remainder being used for the rearing of dairy replacements. It is estimated that pastures used for dairy production produce an average of 9 tonnes of dry matter per hectare of which 7 tonnes can be utilised as grazed grass and silage. It is believed that this production can be realistically increased to 14 tonnes grass grown and 12 tonnes utilised. There is an economical advantage of increasing the amount of grass grown as there is a benefit of €160/ha for every extra tonne of grass utilised (Teagasc & The Department of Agriculture). Teagasc define a typical grass-based system of dairy production to consist of 75% grazed grass in the cow's diet, together with 15% to 20% grass silage, supplemented with 5% to 10% of concentrate feeds.

Improving productivity per cow within grazing systems relies upon management strategies extrinsic and intrinsic to the animal. Extrinsic to the cow and critical to improving production, is grazing management, which involves the optimisation of fertilizer application, use of legumes, stocking rate, herbage allowance (Boval and Dixon 2012), post-grazing residuals and grass budgeting. Intrinsic to the cow is her genetic make-up, fertility, health status, voluntary grass intake, feed conversion efficiency and energy utilisation/budgeting for example.

Automatic Milking Management System in Relation to Pasture in Ireland

Automatic milking systems are relatively new to the Irish dairy industry and subsequently their management in relation to pasture has been to use existing grazing techniques developed and optimised for a conventional system. The majority of AM systems in Ireland are integrated with grazing and have proven to work well when combined with existing grazing management used with the conventional system such as rotational strip grazing, incorporating a spring grazing planner and building autumn grass covers in preparation for the following year.

With an AM the farm area is either divided into either 2 or 3 sections known as an AB or ABC system of grazing. In an ABC grazing system with automatic milking the farm is divided into 3 sections, approximately equal in size. Cows have access to a grazing in each section for 8 hours each day. In an AB grazing system with automatic milking the farm is divided into 2 sections, approximately equal in size. Cows have access to a grazing in each section for 12 hours each day. The cow voluntarily decides to leave the field to travel to the milking yard. The cow is motivated to leave the field when the grass has been grazed, with the trained knowledge that there is access to new grass in another section.

Cows enter the milking yard through non-return gates specific to each section. In order to access the new grass the cow must pass through the milking yard where she can be drafted for milking, when she is due for milking, before going to the next field. In both AB and ABC systems cows enter the yard through non-return gates specific to each section. However, in an ABC system one of these entry points will have to cross paths with an exit point to one of the sections.

Once cows enter the yard they can make their way to either the robot or to a post-selection drafting gate where an on-cow tag is identified. At the robot the cow is either milked or “rejected” and not milked, and at the post-selection drafting gate is either returned to the yard or allowed access to grass. These outcomes depend on the time since her previous milking. If the previous milking failed she is directed back to the yard by the drafting gate before being allowed to grass.

An alternative yard layout includes a pre-selection drafting gate, whereby cows enter an “outer yard” first and make their way to the pre-selection drafting gate where the on-cow tag is identified. Depending on the time since her previous milking, the cow is either allowed access to another yard in front of the robot or she is directed straight out to grass. After milking and before going to grass cows go through a “post-selection gate”. This removes the necessity for rejecting cows at the robot. Therefore, more time is allocated to milking rather than rejecting cows.

The times in the day that the cows are granted access to each section are pre-programmed by the farmer on the AMS PC and it is common practise to ensure there is little variation in these times over short periods as it allows cows to develop a routine and consistent milking intervals. The farmer can also have control the milking permission of each cow by adjusting the number of milking visits each cow is permitted in the day. In the Irish spring compact-calving system the majority of cows reach peak milk production simultaneously and therefore strategies that enable a farmer to maximise their output and AMS utilisation at this time would be very beneficial.

Breeding in the Irish Dairy Herd

Within in dairy herds breeding contributes to half the performance gains and the genetic gain from informed and good breeding decisions is cumulative and permanent. Cross-breeding also provides dairy farmers an opportunity to improve upon past selection programmes that have been in place on farm. In Ireland the economic breeding index (EBI) is used to describe the expected profitability per lactation of the progeny of the bull. The EBI consists of 6 sub-indexes: (1) Milk production sub index – includes milk, fat and protein yield, (2) Fertility sub index – includes calving interval (measure of fertility) and survival to the subsequent lactation, (3) Maintenance sub index – includes the cost of growing and maintaining the progeny of an animal differing in size (i.e. bigger animals require more feed to attain that weight and also maintain that weight), (4) Calving performance sub index – includes calving difficulty, gestation length and calf mortality, (5) Beef performance sub index – includes traits associated with cull cow value and progeny carcass value and (6) Health sub index – includes udder health and lameness.

The key principals of dairy breeding in Ireland revolve around increasing the herd EBI so that younger animals within the herd have subsequent higher EBI each year. An increase by €5 in the EBI of the herd is targeted and the average EBI of all bulls used for breeding is targeted at €120 greater than the EBI of the herd. The effect of heterosis (or hybrid vigour) achieved through cross-breeding can be used to increase profits and performance over and above their parental mean (http://www.teagasc.ie/dairy/breeding/docs/Breeding.pdf).

Three Breeds Compared in AM Systems with Grazing

The Norwegian Red (NR) dairy cow breed has been historically selected for improved fertility and health over a number of decades. Teagasc research in Ireland has indicated that although this pure-breed NR produce less in terms of milk volume than Holstein-Friesians (HF) there is little difference in milk solids between HF and NR-cross breeds. Previous research has also indicted that NR ^{x} HF cows produced an additional €130 in profit per lactation compared to HF cows, predominantly due to enhanced fertility and survival in the herd (http://www.teagasc.ie/dairy/breeding/docs/Breeding.pdf).

Other Irish research by Teagasc has shown that compared to HF cows pure-bred Jersey and Jersey cross-bred cows produced less milk. However, the milk solids from pure-bred Jerseys and HF cows was similar although the milk solids from first cross Jerseys was better than either pure-bred Jersey or HF cows. The reproductive performance of Jersey cross-bred has been shown to be better than that of pure-bred Jersey and HF cows. Jersey cross-breeds have also been shown to have great feed efficiency and lower calf and cull cow price compared to HF cows. An Irish study on the Teagasc Ballydague farm concluded that first cross Jerseys were €180 more profitable per lactation than the HF cows in the study (http://www.teagasc.ie/dairy/breeding/docs/Breeding.pdf).

Experiments

Background

Automatic milking systems (AMS) are relatively new to Ireland and their successful integration with grazing is reliant upon the voluntary movement of cows within the farm system 24 hours a day. The cow decides when to leave the field, volunteer for milking and the robot milks the cow. This decision is motivated by the trained knowledge that new grass is available every 8 or 12 hours in a system with 3 or 2 grass allocations per day which are accessible upon passing through the milking yard. In Ireland milk production systems, including those integrated with automatic milk, are pasture-based compact spring-calving with the aim to make the most out of the abundant supply of grass which is the cheapest feed source to provide for the high energy demands of lactating cows. In order to take advantage of the seasonal grass growth and production profile in Ireland it is important for famers to have a herd with a high pregnancy rate and a short compact breeding season to achieve a concentrated calving period the following year. To achieve this, the type and breed of cow needs to be efficient at converting grass to milk solids and have adequate fertility so that they can conceive and become pregnant easily.

Previous research conducted at Teagasc Moorepark in Ireland has indicated differences between cross-bred Norwegian Reds, Jerseys crossed with Holstein Friesians and Holstein Friesian cows in the context of Irish seasonal grass-based production. Compared to Holstein-Friesians, Norwegian Red cows were more likely to remain in the herd as they had a median survival of 3.9 lactations as opposed to 1.9 lactations for the Holstein-Friesians. Norwegian Red cows are suited to the seasonal grass-based system of milk production as they portrayed favourable traits such as superior reproductive efficiency, udder health and moderate size, however, they produced slightly (3%) less milk compared to Holstein Frisians (Walsh *et al.* 2008). Crossing Norwegian Red with Holstein Frisian cows has been shown to improve fertility while not compromising the productivity of the herd (Buckley and Shalloo 2009). Fertility traits of Jersey x Holstein Friesian cows, assessed in a study by Prendiville *et. al* (2011), were better than those of Holstein cows across three different grass-based systems of production. Additionally, this study also indicated that there was no difference in milk solids between the two genotypes which received moderate levels of concentrate.

It is evident from previous Irish research that there are distinct advantages of crossing Jersey and Norwegian Red cows with other breeds to enhance fertility and longevity within the herd without compromising milk production in a grass-based production system. Although these traits will remain essential to the farmer in his/her selection of breed type and management, there has not yet been information available to him/her in relation to performance indicators in an automatic milking system relating to these breeds. Therefore, the aims of these studies were to:

Experiment (1): Examine the effect of breed during summer in a compact spring-calving Irish dairy herd milking on an automated milking system.

Experiment (2): Examine the effect of breed and concentrate supplementation during autumn in a compact spring-calving Irish dairy herd milking on an automated milking system.

Experiment 1 - The effect of breed during summer in a compact spring-calving Irish dairy herd in mid-lactation milking on an automated milking system

Experiment 1 - Material and methods

Farm Layout and Grass Management

A single unit Fullwood Merlin 225 automated milking system (AMS) (Fullwood Ltd., Kanturk, Co. Cork, Ireland) was situated on a 25.2ha farm located in the south of Ireland on the Teagasc Moorepark Dairygold Research farm. The grazing platform was divided into 3 grazing sections; A (7.7ha), B (9ha) and C (8.5ha). Cows moved voluntarily to and from the paddock, passing through the milking yard, between the grazing sections. The herd had access to new pasture from 00:00 in A, 08:00 in B and 16:00 in C (Figure 1). This study was carried out during the summer season when the majority of the herd were in mid-lactation (27/04/2015 to 30/08/2015 = 18 weeks). Twice weekly and prior to each grazing, the sward density and herbage mass (HM) (available grass kg dry matter (DM)/ha above 4cm) were calculated by cutting 2 representative grass strips (1.2 x 6m) using an Agria machine (Etesia UK Ltd., Warwick, UK), weighing the cut grass, measuring 10 pre- and post-cut grass heights within this area and 30 grass heights of the entire paddock with a rising plate meter (NZ Agriworks Ltd t/a Jenquip, New Zealand). A sub-sample of 0.1kg from each cutting was collected and dried for 16 hours at 90°C for dry matter (DM) determination. Grass DM intake was calculated by measuring the density of grass DM (kg/cm^3) and area allocated of the paddock prior to grazing to determine the kg DM of grass allocated to the herd. Using the post-grazing heights, the kg of grass that remained from the amount that was allocated was used to calculate the kg of DM that was removed. The grazing area was allocated based on a demand of 22.6kg grass DM/cow/day which was distributed over the 3 grazing sections in a 24h period (Table 1). Pasture management involved strip grazing and only back grazing an area for 1 day if the post grass height was greater than 6cm from the previous grazing. Pre- and post-grazing heights were measured prior to and after each grazing using a Jenquip rising plate meter (NZ Agriworks Ltd t/a Jenquip, New Zealand). The grass DM removed for each grazing was calculated for each grazing to estimate the herd daily grass intake.

Herd Description and Experimental Design

Within the 80 cow herd 46 multiparous cows were assigned to one of three experimental groups defined based on breed: (1) Holstein Friesian (n=15), (2) Jersey x Friesian (n=15) and (3) Norwegian Red crosses (n=16). The cows within these groups were balanced for parity and days in milk. Prior to the commencement of the experimental trial period, on the 27/04/2015, all cows had a milking permission of 2 times per day and received 0.5kg of concentrate, using a fixed feeding routine independent of milk yield, between the 20/04/2015 to the 26/04/2015. This period was implemented in order to allow cows to adjust to these conditions before the experiments began and these conditions continued during the experimental trial period for all 80 cows in the herd form the 27/04/2015 to the 30/08/2015, a total of 18 weeks.

Statistical Analysis

Data collected 7 days prior to treatment implementation between the 20/04/2015 and the 26/04/2015 were averaged and used as a baseline covariate. During the baseline and trial periods dependent variables were averaged per cow per week. The effect of milking permission treatments was analysed on the dependant variables: (1) Feed intake/cow/day, (2) milking frequency/cow/day, (3) milking interval/cow/visit, (4) Activity/cow/hour, (5) milk yield/cow/visit, (6) milk yield/cow/day, (7) milk duration/cow/visit, (8) milk duration/cow/day, (9) return time/cow/visit, (10) return time/cow/day, (11) wait time/cow/visit and (12) wait time/cow/day. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc analysis. The fixed effects were breed, week, lactation, days in milk, baseline averages as covariates and week x breed interaction. Least squares mean and standard errors of each dependent variable were outputted for breed.

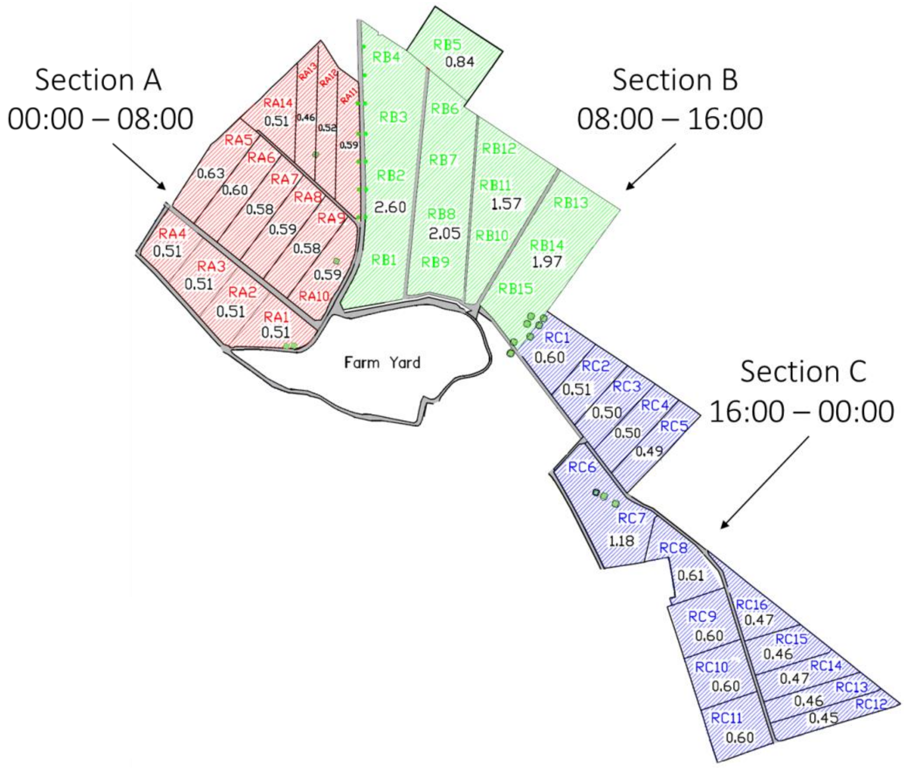

Figure 1: The area of the Teagasc Moorepark Dairygold research farm dedicated to cows milking on an automated milking system. It is divided into three grazing sections A (7.7ha), B (9ha) and C (8.5ha). Cows have access to new pasture from 00:00 to 08:00 in A, 08:00 to 16:00 in B and 16:00 to 00:00 in C.

Experiment 1 - Results and discussion

In Ireland dairy farmers have a compact spring-calving herd so that high energy demanding lactating cows can be fed grass which is the cheapest feed that farmers can provide. Grass growth per day begins to increase from 8kg/ha per day in January to 50kg/ha per day at the beginning of April and falls below 50kg/ha per day in early September. This study focused on the summer season between April and August when there is a plentiful supply of grass and when the majority of the herd are in mid-lactation. The aim of the study was to assess the effect of breed on milk production and cow traffic during the summer season in a spring-calving pasture-based herd in mid-lactation.

In the present study cows were offered 0.5kg concentrate and 22.6kg grass DM/cow per day, so that the proportion of grass in the cow's diet was 98%. Throughout this study cows within the herd had equal access to the same grazing allocations each day. The average pre-grazing available herbage mass across all sections was 1646kg DM/ha (A – 1647kg, B – 1583kg and C – 1709kg DM/ha). The average daily grass DM allowance per cow was 22.6kg (A – 7.4kg, B – 8.0kg and C – 7.2kg) and average daily estimated grass DM intake per cow was 17.6kg (A – 5.7kg, B – 6.3kg and C – 5.5kg). The average post grazing height was 5.6cm (A – 5.6cm, B – 5.5cm and C – 5.6cm) (Table 1).

The main effect of breed was significant for the dependent variables: milk duration per visit and day, and wait time per visit and day. Interestingly there was no difference in milk production between the breeds during the summer season. NR^x cows had a significantly lower milk duration per visit (8mins) compared to the JE^x cows (8.6mins) and HF cows (8.4mins). There was no difference between HF and NR^x in milk duration per day, however, NR^x cows had significantly lower milk duration per day (10.9mins) than JE^x cows (11.5mins). NR^x cows waited significantly less per visit (0.93hrs) than HF cows (1.27hrs) and also the NR^x wait time was significantly less per day than the JE^x (1.3hrs) (Table 2 and Table 3).

Experiment 1 - Conclusion

Cow traffic variables rather than milk production variables were most different between breeds and there were no differences between HF and JE^x. HF spent more time milking per visit and day and spent more time waiting per visit compared to NR^x. JE^x spent more time milking per visit and waiting per day than NR^{x}. NR^{x} moved through the system more efficiently that HF and JE^{x}.

Table 1: Average and total daily herbage allowance and allocation characteristics during summer in Ireland for grazing blocks A, B and C.

	A	**B**	**C**	**Average**
Number of Cows				80
Pregrazing (cm)	12.0	11.4	11.8	11.7
Postgrazing (cm)	5.6	5.5	5.6	5.6
Density (kg of DM/cm per ha)	245.2	243.7	254.7	247.9
Herbage mass >4 cm (kg of DM/ha)	1647	1583	1709	1646

	A	**B**	**C**	**Total**
Herbage allocated (kg DM/herd)	597.2	645.1	574.7	1817.0
Area offered (m^2/cow per d)	32.5	39.1	33.1	104.8
Herbage allocated (kg DM/cow)	7.4	8.0	7.2	22.6
Herbage removed (kg DM/cow)	5.7	6.3	5.5	17.6

Table 2: The effect of breed on cow production and traffic variables in summer. Breeds include Holstein Friesian (HF), Jersey ^{x} Holstein Friesian (JE^{x}) and Norwegian Red^{x} (NR^{x}). Dependent variables include: feed intake (FI) milking frequency (MF), milking interval (MI hrs), activity (steps/hr), milk yield (MY kg), milking duration (MD min), return time (RT hrs) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED).

	HF		**JE^{x}**		**NR^{x}**		***p***
	LSM	**SE**	**LSM**	**SE**	**LSM**	**SE**	**value**
FI/d (kg)	0.46	0.01	0.44	0.01	0.45	0.01	NS
MF/d	1.4	0.04	1.3	0.04	1.4	0.03	NS
MI/v (hrs)	16.2	0.6	16.4	0.6	16.1	0.5	NS
Activity/d	631	23	704	24	683	23	NS
MY/v (kg)	14.3	0.4	12.8	0.4	13.3	0.4	NS
MY/d (kg)	18.2	0.9	16.0	1.0	16.7	0.9	NS
MD/v (mins)	8.4[a]	0.1	8.6[a]	0.1	8.0[b]	0.1	0.0003
MD/d (mins)	11.5[a]	0.2	11.5[a]	0.2	10.9[b]	0.2	0.0091
RT/v (hrs)	7.3	0.4	7.7	0.4	7.0	0.4	NS
RT/d (hrs)	16.8	0.3	15.6	0.3	17.0	0.3	NS
WT/v (hrs)	1.27[a]	0.14	1.49[ab]	0.14	0.93[b]	0.13	0.0191
WT/d (hrs)	1.62[ab]	0.14	1.90[a]	0.14	1.30[b]	0.14	0.0153

Table 3: The effect of breed on cow production and traffic variables in summer. Breeds include Holstein Friesian (HF), Jersey ^{x} Holstein Friesian (JE^{x}) and Norwegian Red^{x} (NR^{x}). Dependent variables include: milking duration (MD min) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc *p*-values are represented.

	HF		JE^{x}		NR^{x}		HF v JE^{x}		HF v NR^{x}		JE^{x} v NR^{x}	
	LSM	**SE**	**LSM**	**SE**	**LSM**	**SE**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**
MD/v (mins)	8.4[a]	0.1	8.6[a]	0.1	8.0[b]	0.1	-0.24	NS	0.37	0.030	0.62	0.0003
MD/d (mins)	11.5[a]	0.2	11.5[a]	0.2	10.9[b]	0.2	0.02	NS	0.52	NS	0.50	NS
WT/v (hrs)	1.27[a]	0.14	1.49[ab]	0.14	0.93[b]	0.13	-0.22	NS	0.34	0.017	0.56	NS
WT/d (hrs)	1.62[ab]	0.14	1.90[a]	0.14	1.30[b]	0.14	-0.28	NS	0.32	NS	0.60	0.011

Experiment 2 – The effect of breed and concentrate during autumn in a compact spring-calving Irish dairy herd milking on an automated milking system

Experiment 2 - Methods and Materials

Farm Layout and Grass Management

A single unit Fullwood Merlin 225 automated milking system (AMS) (Fullwood Ltd., Kanturk, Co. Cork, Ireland) was situated on a 25.2ha farm located in the south of Ireland on the Teagasc Moorepark Dairygold Research farm. The grazing platform was divided into 3 grazing sections; A (7.7ha), B (9ha) and C (8.5ha). Cows moved voluntarily to and from the paddock, passing through the milking yard, between the grazing sections. The herd had access to new pasture from 00:00 in A, 08:00 in B and 16:00 in C (Figure 1). This study was carried out during the autumn season when the majority of the herd were in late-lactation (14/09/2015 to 18/10/2015 = 5 weeks). Twice weekly and prior to each grazing, the sward density and herbage mass (HM) (available grass kg dry matter (DM)/ha above 4cm) were calculated by cutting 2 representative grass strips (1.2 x 6m) using an Agria machine (Etesia UK Ltd., Warwick, UK), weighing the cut grass, measuring 10 pre- and post-cut grass heights within this area and 30 grass heights of the entire paddock with a rising plate meter (NZ Agriworks Ltd t/a Jenquip, New Zealand). A sub-sample of 0.1kg from each cutting was collected and dried for 16 hours at 90°C for dry matter (DM) determination. Grass DM intake was calculated by measuring the density of grass DM (kg/cm^3) and area allocated of the paddock prior to grazing to determine the kg DM of grass allocated to the herd. Using the post-grazing heights, the kg of grass that remained from the amount that was allocated was used to calculate the kg of DM that was removed. The grazing area was allocated based on a demand of 18kg grass DM/cow/day which was distributed over the 3 grazing sections in a 24h period (Table 4). Pasture management involved strip grazing and only back grazing an area for 1 day if the post grass height was greater than 6cm from the previous grazing. Pre- and post-grazing heights were measured prior to and after each grazing suing a Jenquip rising plate meter (NZ Agriworks Ltd t/a Jenquip, New Zealand). The grass DM removed for each grazing was calculated for each grazing to estimate the herd daily grass intake.

Herd Description and Experimental Design

Within the 80 cow herd 47 multiparous cows were assigned to one of six experimental groups defined based on breed and level of concentrate. The experimental design was a 3x2 factorial with 3 different breeds with either a high concentrate level (2.65kg) or low concentrate level (0.5kg): (1) Holstein Friesian high concentrate (n=8), (2) Holstein Friesian low concentrate (n=7), (3) Jersey x Friesian high concentrate (n=8), (4) Jersey x Friesian low concentrate (n=7), (5) Norwegian Red crosses high concentrate (n=8) and (6) Norwegian Red crosses low concentrate (n=9). The cows within these groups were balanced for parity and days in milk. Prior to the commencement of the experimental trial period, on the 14/09/2015, all cows had a milking permission of 2 times per day and the different concentrate levels were implemented using a fixed feeding routine independent of milk yield, over a two week period between the 31/08/2015 to the 13/09/2015. This period was implemented in order to allow all cows to adjust to these conditions before the experiment. These conditions were continued during the experimental trial period from the 14/09/2015 to the 18/10/2015, which was a total of 5 weeks.

Statistical Analysis

Data collected 7 days prior to treatment implementation between the 24/08/2015 and the 30/08/2015 were averaged and used as a baseline covariate. During the baseline and trial periods dependent variables were averaged per cow per week. The effect of milking permission treatments was analysed on the dependant variables: (1) Feed intake/cow/day, (2) milking frequency/cow/day, (3) milking interval/cow/visit, (4) Activity/cow/hour, (5) milk yield/cow/visit, (6) milk yield/cow/day, (7) milk duration/cow/visit, (8) milk duration/cow/day, (9) return time/cow/visit, (10) return time/cow/day, (11) wait time/cow/visit and (12) wait time/cow/day. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc analysis. The fixed effects were concentrate, breed, week, lactation, days in milk, baseline averages as covariates and treatment x breed interaction. Least square means and standard errors of each dependent variable were outputted for treatment and breed.

Experiment 2 - Results and Discussion

In Ireland dairy farmers have a compact spring-calving herd so that high energy demanding lactating cows can be fed grass which is the cheapest feed that farmers can provide. Grass growth per day begins to increase from 8kg/ha per day in January to 50kg/ha per day at the beginning of April and falls below 50kg/ha per day in early September. This study focused on the autumn season during September and October when quality and grass growth is beginning to decline. The aim of the study was to assess the effect of breed and level of concentrate on milk production and cow traffic during autumn in a spring-calving pasture-based herd in late-lactation.

In the present study cows were offered either 0.5kg or 2.65kg of concentrate and 18kg of grass DM/cow per day during the autumn period. Therefore, grazed grass DM had the potential to constitute approximately 97.3% (with 0.5kg concentrate) or 87.2% (with 2.65kg concentrate) of the cow's diet. Throughout this study cows within the herd had equal access to the same grazing allocations each day. Previous Irish studies have assessed different levels of daily herbage allowance in combination with different levels of concentrate and silage with cows milked in conventional milking systems. Due to the limitations of a single AMS unit on a single block of land during this study it was not feasible to have concurrent differing levels of daily herbage allowance as a treatment. However, previous Irish studies that have assessed differing levels of supplementation during spring and autumn are invaluable to the interpretation of milk production and grass measurement variables in the present study. The average pre-grazing available herbage mass across all sections was 1949kg DM/ha (A – 2100kg, B – 1937kg and C – 1809kg DM/ha). The average daily grass DM allowance per cow was 18kg (A – 5.6kg, B – 6.1kg and C – 6.3kg) and average daily estimated grass DM intake per cow was 15.5kg (A – 4.8kg, B – 5.1kg and C – 5.7kg). The average post grazing height was 5.3cm (A – 5.4cm, B – 5.6cm and C – 5.0cm) (Table 4).

In addition to reduced herbage availability in autumn (Creighton et al 2011) the herbage is also of a poorer quality compared to other times of the year (McCarthy et al 2013; Tuno et al 2014). Grazing pastures in early spring infers a positive carryover effect by increasing sward utilisation and herbage quality for the remaining grazing season (O'Donovan et al 2004). The decrease in grass quality and/or quantity during the autumn in Ireland has as negative impact on the quantity of dry matter intake. The decrease in pasture dry matter intake per kilogram of concentrate feed offered is known as the substitution rate and is affected by multiple factors such as daily herbage allowance, cow genetic merit (Horan et al 2006), concentrate allowance (Stockdale 2000) stage of lactation, parity and pasture quality (Bargo et al 2003). When the substitution rate is low, a greater milk response to the supplement offered will be achieved.

A recent Irish study by Reid et al (2015) found that a high milk response can be achieved in late lactation during autumn by reducing the substitution rate which increases milk yield and milk solids at this time. Compared to supplementing spring-calving dairy cows with silage in autumn, concentrate supplementation increased milk yield and milk solids. The group receiving 14kg grass DM/cow per day and 3kg concentrate DM/cow per day produced significantly more milk and milk solids than cows receiving only 17 and 14kg of grass DM/cow per day. However, the same study suggested that milk produced from cows on a grass only diet might be more suitable for processing compared to milk produced from cows with diets that are highly supplemented. The process-ability of milk is its suitability for processing into dairy products and this can be improved by increasing particular N components in the milk, specifically CN (Hermansen et al., 1999).

Lyons *et. al* (2013) compared the use of supplementary feed pre- and post-milking in a grazing system and observed a reduced voluntary return time of cows from the paddock with pre-milking supplementation. Reduced pre-milking waiting time enhances animal welfare and was achieved by providing concentrate at the milking unit in a voluntary robotic rotary system (Scott et. al 2014). In a spring calving, pastured based system of farming the availability of grass is a key factor in a farmer’s management decisions relating to grass budgeting and concentrate supplementation. During a period when there is a grass deficit, as a result of reduced grass growth and quality in the latter end of the year for example, the dairy system needs to be sufficiently flexible to react and compensate for the shortage of grass without dramatically impacting milk production and in the case of an AMS, cow traffic.

The results indicated that for the dependent variables of milk production (milk yield per visit and day), feed intake, activity and cow traffic (milking frequency per day, milking interval per visit, milking duration per visit, return time per visit and day, and waiting time per visit and day) the interaction between breed and concentrate was not significant. However, there was a significant interaction between breed and concentrate for the dependent variable milk duration per day which will be discussed later.

The main effect of breed was significant for the dependent variables: feed intake per day, milking interval per visit, wait time per visit and wait time per day. The main effect of concentrate was significant for the dependent variables: feed intake per day, milking interval per visit, milk yield per day. Interestingly both breed and concentrate had a significant effect on milking interval per visit. NR^x cows had a significantly lower milking interval (16.7hrs) compared to the JE^x cows (18.9hrs) and there was no difference between HF and NR^x or HF and JE^x cows (Table 5 and Table 6). Cows given higher levels of concentrate had a significantly shorter milking interval (17.2hrs) compared to cows given a higher milking interval (18.7hrs). It was evident that the fixed feeding regime resulted in the desired treatments as cows offered the higher level of concentrate also consumed significantly more (1.9kg) than the cows offered the lower level of concentrate (Table 7 and Table 8). Within the breed comparisons, HF consumed significantly more (0.1kg) that the JE^x and the NR^x also consumed significantly more (0.11kg) than the JE^x. Although there was a significant difference of concentrate intake between the breeds, there was no difference in milk yield between them (Table 5 and Table 6). However, cows offered the higher level of concentrate produced significantly more milk per day (0.8kg) than cows offered the lower concentrate level. The level of concentrate did not influence the length of time that cows spent in the waiting yard to be milked, which is in agreement with the results in deliverable 1.1 (Table 7 and Table 8). However, between breeds JE^x waited significantly longer than HF (0.51hrs) and NR^x per visit and significantly longer per day (0.53hrs) than HF (Table 5 and Table 6). There was a significant interaction between breed and concentrate for milk duration per day and this will be assessed further in subsequent analysis of the data as part of a PhD thesis (Table 9 and Table 10).

Experiment 2 - Conclusions

There was a significant interaction between concentrate level and breed for milk duration per day. Concentrate and breed had a significant effect on feed intake and milking interval. Concentrate significantly affected yield per day whereas breed did not. Breed significantly effected wait time per day and visit whereas concentrate did not. JE^x consumed significantly less than HF and NR^x cows. JE^x waited significantly longer than HF and NR^x cows. JE^x had a significantly longer MI than NR^x cows. JE^x had a significantly longer waiting time per visit and day than HF cows.

Table 4: Average and total daily herbage allowance and allocation characteristics during autumn in Ireland for grazing blocks A, B and C.

	A	**B**	**C**	**Average**
Number of Cows				80
Pregrazing (cm)	13.6	13.6	13.8	13.7
Postgrazing (cm)	5.4	5.6	5.0	5.3
Density (kg of DM/cm per ha)	245.5	244.4	220.8	236.9
Herbage mass >4 cm (kg of DM/ha)	2100	1937	1809	1949
Herbage allocated (kg DM/herd)	447.8	489.0	506.0	1442.8
	A	**B**	**C**	**Total**
Area offered (m^2/cow per d)	21.9	23.5	25.4	70.7
Herbage allocated (kg/cow)	5.6	6.1	6.3	18.0
Herbage removed (kg/cow)	4.8	5.1	5.7	15.5

Table 5: The effect of breed on cow production and traffic variables in autumn. Breeds include Holstein Friesian (HF), Jersey x Holstein Friesian (JEx) and Norwegian Red x (NRx). Dependent variables include: feed intake (FI) milking frequency (MF), milking interval (MI hrs), activity (steps/hr), milk yield (MY kg), milking duration (MD min), return time (RT hrs) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED).

	HF		**JE^{x}**		**NR^{x}**		***p* value**
	LSM	**SE**	**LSM**	**SE**	**LSM**	**SE**	
FI/d (kg)	1.37	0.03	1.27	0.03	1.38	0.03	0.015
MF/d	1.3	0.03	1.2	0.03	1.3	0.03	NS
MI/v (hrs)	18.3	0.5	18.9	0.5	16.7	0.5	0.009
Activity/d	453.5	16.9	469.1	17.1	501.7	15.9	NS
MY/v (kg)	9.4	0.3	9.5	0.3	9.2	0.3	NS
MY/d (kg)	12.2	0.3	11.7	0.3	11.7	0.3	NS
MD/v (mins)	6.4	0.2	6.6	0.2	6.5	0.1	NS
MD/d (mins)	8.0	0.2	8.2	0.2	8.4	0.2	NS
RT/v (hrs)	9.0	0.4	9.5	0.4	8.2	0.4	NS
RT/d (hrs)	17.8	0.4	17.0	0.5	17.1	0.4	NS
WT/v (hrs)	0.85	0.13	1.36	0.13	0.92	0.12	0.01
WT/d (hrs)	1.05	0.14	1.58	0.14	1.13	0.13	0.02

Table 6: The effect of breed on cow production and traffic variables in autumn. Breeds include Holstein Friesian (HF), Jersey ^{x} Holstein Friesian (JE^{x}) and Norwegian Red ^{x} (NR^{x}). Dependent variables include: feed intake (FI kg), milking interval (MI hrs) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc *p-values* are represented.

	HF		**JE^{x}**		**NR^{x}**		**HF v JE^{x}**		**HF v NR^{x}**		**JE^{x} v NR^{x}**	
	LSM	**SE**	**LSM**	**SE**	**LSM**	**SE**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**
FI/d (kg)	1.37	0.03	1.27	0.03	1.38	0.03	0.10	0.037	-0.01	NS	-0.11	0.0232
MI/v (hrs)	18.3	0.5	18.9	0.5	16.7	0.5	-0.65	NS	1.55	NS	2.20	0.009
WT/v (hrs)	0.85	0.13	1.36	0.13	0.92	0.12	-0.51	0.017	-0.07	NS	0.44	0.047
WT/d (hrs)	1.05	0.14	1.58	0.14	1.13	0.13	-0.53	0.027	-0.08	NS	0.45	NS

Table 7: The effect of concentrate on cow production and traffic variables in autumn. Concentrate levels were 0.5kg for the low group and 2.65kg for the high group. Dependent variables include: feed intake (FI) milking frequency (MF), milking interval (MI hrs), activity (steps/hr), milk yield (MY kg), milking duration (MD min), return time (RT hrs) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED).

	Low		**High**		***p* value**
	LSM	**SE**	**LSM**	**SE**	
FI/d (kg)	0.40	0.02	2.28	0.02	<0.0001
MF/d	1.2	0.03	1.3	0.03	NS
MI/v (hrs)	18.7	0.4	17.2	0.4	0.013
Activity/d	459.4	14	490.1	13	NS
MY/v (kg)	9.07	0.26	9.63	0.25	NS
MY/d (kg)	11.28	0.24	12.08	0.24	0.012
MD/v (mins)	6.44	0.13	6.57	0.12	NS
MD/d (mins)	8.08	0.16	8.37	0.16	NS
RT/v (hrs)	9.52	0.34	8.37	0.33	NS
RT/d (hrs)	17.4	0.4	17.2	0.3	NS
WT/v (hrs)	0.97	0.10	1.08	0.10	NS
WT/d (hrs)	1.16	0.12	1.31	0.11	NS

Table 8: The effect of concentrate on cow production and traffic variables in autumn. Concentrate levels were 0.5kg for the low group and 2.65kg for the high group. Dependent variables include: feed intake (FI kg), milking interval (MI hrs) and milk yield (MY kg) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc *p-values* are represented.

	Low		**High**		**High v Low**	
	LSM	**SE**	**LSM**	**SE**	**Difference**	***p* value**
FI/d (kg)	0.4	0.0	2.3	0.0	-1.9	<0.0001
MI/v (hrs)	18.7	0.4	17.2	0.4	1.5	0.01
MY/d (kg)	11.28	0.24	12.08	0.24	-0.8	0.01

Table 9: The interaction between breed and concentrate on cow production and traffic variables in autumn were assessed. Concentrate levels were 0.5kg for the low group and 2.65kg for the high group. Breeds include Holstein Friesian (HF), Jersey x Holstein Friesian (JE^x) and Norwegian Red x (NRx). Dependent variables include: feed intake (FI) milking frequency (MF), milking interval (MI hrs), activity (steps/hr), milk yield (MY kg), milking duration (MD min), return time (RT hrs) and waiting time (WT hrs) per cow per day (d) and per visit (v). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED).

	Low						**High**						
	HF		**JE^x**		**NR^x**		**HF**		**JE^x**		**NR^x**		***p* value**
	LSM	**SE**	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**	
FI/d (kg)	413.5	42.4	366.1	44.7	415.1	37.1	2322.8	40.0	2165.7	39.4	2341.4	43.0	NS
MF/d	1.2	0.05	1.2	0.05	1.3	0.04	1.3	0.04	1.2	0.04	1.3	0.04	NS
MI/v (hrs)	18.9	0.8	19.3	0.9	18.1	0.7	17.9	0.8	18.3	0.7	15.5	0.8	NS
Activity/d	450	24	456	25	472	21	457	23	482	23	531	23	NS
MY/v (kg)	9.15	0.46	9.24	0.47	8.81	0.40	9.72	0.43	9.67	0.43	9.49	0.43	NS
MY/d (kg)	11.7	0.5	11.7	0.5	10.7	0.4	12.7	0.4	11.7	0.4	12.6	0.4	NS
MD/v (mins)	6.3	0.2	6.6	0.2	6.4	0.2	6.4	0.2	6.7	0.2	6.6	0.2	NS
MD/d (mins)	8.0	0.3	8.4	0.3	7.9	0.2	8.3	0.3	7.9	0.3	9.0	0.3	0.0369
RT/v (hrs)	9.2	0.6	10.2	0.6	9.1	0.5	8.9	0.6	8.8	0.6	7.4	0.6	NS
RT/d (hrs)	17.8	0.6	17.0	0.7	17.4	0.5	17.8	0.6	16.9	0.6	16.8	0.6	NS
WT/v (hrs)	0.81	0.18	1.05	0.19	1.06	0.16	0.87	0.17	1.61	0.17	0.76	0.17	NS
WT/d (hrs)	0.97	0.21	1.24	0.22	1.29	0.19	1.09	0.19	1.88	0.19	0.96	0.19	NS

Table 10: The interaction between breed and concentrate on cow production and traffic variables in autumn were assessed. Concentrate levels were 0.5kg for the low group and 2.65kg for the high group. Breeds include Holstein Friesian (HF), Jersey x Holstein Friesian (JE^x) and Norwegian Red x (NRx). Dependent variable was milking duration (MD min) per cow per day (d). Least squares means (LSM) and standard error (SE) are represented. The statistical model used was a repeated measures ANOVA in SAS (PROC MIXED) and Tukey's post-hoc *p-values* are represented.

	HF		**JE^x**		**HF Low v Je^x Low**		**HF High v Je^x High**		**HF High v Je^x Low**		**HF Low v Je^x High**	
	LSM	**SE**	**LSM**	**SE**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**
MD/d (mins)	8.0	0.3	8.4	0.3	-26.88	NS	26.92	NS	5.01	NS	5.04	NS

	HF		**NR^x**		**HF Low v NR^x Low**		**HF High v NR^x High**		**HF High v NR^x Low**		**HF Low v NR^x High**	
	LSM	**SE**	**LSM**	**SE**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**
MD/d (mins)	8.0	0.3	7.9	0.2	1.63	NS	-38.99	NS	-23.51	NS	-60.87	NS

	JE^x		**NR^x**		**JE^x Low v NR^x Low**		**NR High v Je^x High**		**NR High v Je^x Low**		**NR Low v Je^x High**	
	LSM	**SE**	**LSM**	**SE**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**	**Difference**	***p* value**
MD/d (mins)	8.4	0.3	7.9	0.2	28.52	NS	-65.91	NS	-33.99	NS	3.41	NS

Overall Conclusions

During summer and autumn in a pasture-based spring-calving herd there was no effect of breed on the volume of milk produced per visit or per day. During the summer season there were no differences in cow traffic variables between HF and JE^x, whereas in the autumn period the HF spent less time waiting to milked per visit and per day than the JE^x. The NR^x cows spent less time waiting to be milked per visit than the JE^x during the summer and HF during the autumn. The NR^x cows spent less time waiting to be milked per day than the JE^x during the autumn. During the summer NR^x cows had a shorter milking interval than the JE^x cows and during the autumn period they had a shorter milk duration than HF and JE^x cows per visit and JE^x cows per day. These results would suggest that NR^x and HF cows are more efficient within the system than the JE^x cows when taking cow traffic-ability into consideration. During the autumn period there was a significant interaction between concentrate level and breed for the variable milk duration per day. Concentrate and breed had a significant effect on feed intake and milking interval. Concentrate significantly affected yield per day whereas breed did not.

References

Bargo, F., L. D. Muller, E. S. Kolver, and J. E. Delahoy. 2003. Invited review: Production and digestion of supplemented dairy cows on pasture. Journal of Dairy Science. 86:1–42.

Buckley F and Shalloo L (2009). Crossbreeding – Is it more profitable? Proceedings of the Teagasc National Dairy Conference, 18 November, Mullingar, Co. Westmeath, pp. 93-104.

Creighton, P., E. Kennedy, L. Shalloo, T. M. Boland, and M. O' Donovan. 2011. A survey analysis of grassland dairy farming in Ireland, investigating grassland management, technology adoption and sward renewal. Grass Forage Science. 66:251–264.

Hermansen, J., S. Ostersen, C. Justesen, and O. Aaes. 1999. Effects of dietary protein supply on caseins, whey proteins, proteolysis and renneting properties in milk from cows grazing clover or N fertilized grass. Journal of Dairy Research. 66:193–205.

Horan, B., P. Faverdin, L. Delaby, M. Rath, and P. Dillon. 2006. The effect of strain of Holstein-Friesian dairy cow and pasture-based system on grass intake and milk production. Animal Science. 82:435–444.

Lyons, N.A., Kerrisk, K.L. & Garcia, S.C. (2013). Comparison of 2 systems of pasture allocation on milking intervals and total daily milk yield of dairy cows in a pasture-based automatic milking system. Journal of Dairy Science 96: pp 4397–4405.

McCarthy, B., K. M. Pierce, L. Delaby, A. Brennan, C. Fleming, and B. Horan. 2013. The effect of stocking rate and calving date on grass production, utilization and nutritive value of the sward during the grazing season. Grass Forage Science. 68:364–377.

O'Donovan, M., L. Delaby, and J. L. Peyraud. 2004. Effect of time of initial grazing date and subsequent stocking rate on pasture production and dairy cow performance. Animal Research. 53:489–502.

Prendiville R, Shalloo L, Pierce KM and Buckley F (2011). Comparative performance of Holstein-Friesian, Jersey and Jersey x Holstein-Friesian cows under seasonal pasture-based management. Irish Journal of Agricultural and Food Research 50, 123-140.

Reid, M., M. O'Donovan, J. P. Murphy, C. Fleming, E. Kennedy, and E. Lewis. 2015. The effect of high and low levels of supplementation on milk production, nitrogen utilization efficiency, and milk protein fractions in late-lactation dairy cows. Journal of Dairy Science. 98:5529–5544.

Scott, V.E., Thomson, P.C., Kerrisk, K.L. & Garcia, S.C. (2014). Influence of provision of concentrate at milking on voluntary cow traffic in a pasture-based automatic milking system. Journal of Dairy Science 97: pp 1481–1490.

Stockdale, C. R. 2000. Levels of pasture substitution when concentrates are fed to grazing dairy cows in northern Victoria. Australian Journal of Experimental Agriculture. 40:913–921.

Tuñon, G., E. Kennedy, B. Horan, D. Hennessy, N. Lopez-Villalobos, P. Kemp, A. Brennan, and M. O'Donovan. 2014. Effect of grazing severity on perennial ryegrass herbage production and sward structural characteristics throughout an entire grazing season. Grass Forage Science. 69:104–118.

Walsh S, Buckley F, Berry DP, Rath M, Pierce KM, Byrne N and Dillon P (2007). Effects of breed, feeding system, and parity on udder health and milking characteristics. Journal of Dairy Science 90, 5767–5779.

Sweden – High yield, low proportion of pasture

Background

Swedish Holstein and Swedish Red – basic information

The number of cows in Sweden 2014 was around 344000 (SJV, 2015a) while the number of farms in June 2014 was 4394. The average number of cows per farm was 78 (SJV, 2014) and the total amount of milk produced yearly in Sweden is 2,932,000 tonnes (SJV, 2015b). Two breeds dominate among Swedish milk-producers and in the Swedish official milk recording system, that comprises 86% of all cows, 38.1 % of the cows are of the Swedish Red (SR) breed and 54% are Swedish Holstein (SH). The average milk yield for a dairy cow is 8389kg while the average for an SR and SH cow in the milk recording system is 9529kg energy corrected milk (ECM) and 10239kg ECM, respectively (Växa Sverige, 2015). The SR breed has a higher average fat content in the milk compared with SH, 4.36% and 4.09%, respectively, and the protein content in the milk is also higher for the SR breed with, 3.57% and 3.4% milk protein for the SR and SH breeds, respectively.

Robotic milking and grazing in Sweden – short background information

In Sweden, automatic milking (AM) is becoming increasingly important as the amount of milk produced in AM systems and the number of cows milked with robots is continuously increasing. Today, 34.2% of the milk produced in Sweden is produced on farms with an AM system, a total of 1064 farms that constitute 24.2% of the dairy farms in Sweden. The average number of robots per farm with AM is 1.7 robots (Växa Sverige, 2015). Swedish dairy production is intensive and the dairy cow diet is based on high quality grass silage and concentrates throughout the winter season, and in many cases, this diet is also common during the summer (see below).

Animal welfare legislation in Sweden stipulates that dairy cows must be at pasture during the summer. The law requires that animals come out into the pasture area at least once a day and have a minimum of 6 hours daily access to the pasture area that must be covered by vegetation. The minimum grazing period is also defined by law and varies between a total of four months in the south to two months in the north with various details about how the grazing during these months may be organized. As a consequence of this legislation, grazing is an important issue for dairy farmers. Furthermore, almost 13% of the total milk production in Sweden is organic (SJV, 2015c).

For organic farmers, pasture management is a subject of major importance as the rules for organic production require that the cows' diet contains a significant proportion of pasture (at least 6kg DM) during the grazing season. For both conventional and organic farmers the issue of how to combine pasture with AM is under continuous discussion.

Most conventional, non-organic dairy farms with AM in Sweden practice full indoor feeding with concentrates and silage during the grazing season. To fulfil the Swedish law that requires that all dairy cows should have access to pasture during at least 6 hours per day these animals are usually allowed to go out on an exercise pasture that is fairly small. Due to the small pasture area and the high grazing pressure applied, pasture is in most cases regarded as a question of exercise and welfare only and not included in the calculated ration for the cow, even though there may be a small amount of intake, especially in early season when pasture growth is abundant. The choice of full indoor feeding is in most cases based on a concern that the farmer wishes to ensure that the cows get sufficient nutrients to maintain a high production level throughout the year. A number of experiments have been performed during the last few years to see if the full indoor feeding system can be challenged by a grazing system that includes up to around 25% pasture in the diet on a dry matter (DM) basis. The objective has been to see if higher milk yield and/or lower feed costs could be achieved by offering cows approximately 25% of DM intake as pasture in the diet. The strategy would be to combine indoor feeding part of the day with grazing part of the day. If this management strategy can prove to be economical, production pasture may become more common among conventional, non-organic farms.

According to the rules for organic milk production in Sweden, the dairy cow diet should contain at least 6kg DM pasture during the grazing season. Thus, organic farmers offer their cows production pasture with around 50% of the roughage indoors (KRAV, 2015). As the amount of concentrate in the diet can be up to 50% of the diet during the first part of lactation and a little less in later stages of lactation, the proportion of pasture in the entire diet will, in practice, usually not exceed 25-30% of total DM intake. This is substantially more than the amount of pasture in the diet of cows with predominately exercise pasture in conventional production. Thus, the interest for how to combine AM with pasture is presently mainly found among the organic farmers.

Due to climatic conditions, regulations and tradition, Swedish cow barns have a high building standard and are technically advanced. This gives a high cost per cow in the system and therefore, most Swedish farmers aim at a high milk yield per cow rather than producing the same amount of milk with more cows that have a lower production level.

Two Swedish breeds compared in AM systems with grazing

The two most common Swedish breeds, SR and SH that together include more than 90% of the Swedish dairy cows, have been included in three experiments where questions with relevance on how to combine automatic milking and grazing have been studied. An evaluation and comparison of the two breeds has been performed with regard to grazing behaviour, cow traffic and milk yield variables during the grazing season and conclusions have been drawn.

The main objective of this study has been to evaluate advantages and/or disadvantages of these two breeds in a milk production system that combines AM with grazing. The performance of the two breeds have been compared and evaluated with regard to grazing behaviour, cow traffic and milk yield variables. The hypotheses of the breed evaluation in these studies were:

1) Swedish Holstein will not differ in milk yield or milk composition from the Swedish Red breed as an effect of the grazing situation or the grazing treatments imposed in the experiments, i.e. differences during the grazing season will be similar to the average overall breed differences.

2) The Swedish Red breed will have a lower milking frequency compared with Swedish Holstein.

3) The Swedish Red breed will spend more time outdoors and more time grazing compared with the Swedish Holstein breed.

Experiment 1 – Exercise pasture compared with production pasture in a daytime grazing system

Experiment 1 – Material and methods

The experimental results, with regard to treatments, have been described in Deliverable 1.1. and in a conference paper (Spörndly et al., 2015). The focus in the present deliverable is on the effects of breed and in some cases interactions between breed and treatment.

The experiment was carried out with 40 cows (15 primiparous) of the SH and SR breeds during 5 weeks in 2013 with a similar proportion (36-38%) of primiparous cows in each breed. The number of cows of the SH breed was 14, which corresponded to 35% of the cows in the experiment, the remaining 26 cows were of the SR breed. Half of the heifers and half of the multiparous cows of each breed were randomly assigned to one of the two treatments leaving the remaining cows for the other treatment.

Milk yield, milking frequency, feed intake indoors and time on pasture were recorded automatically. Milk samples were collected for analysis before experimental start and thereafter every second week. Behaviour observations were performed over three days distributed over the experimental period. During these observations days, all cows on pasture were observed every 15 minutes and the following behaviours were recorded: location (cow lane or pasture/exercise area), position (standing or lying) and activity (grazing or other).

Pasture height and pasture allowance were measured daily, and samples of pasture and supplementary feed were collected daily for analysis to determine nutrient composition.

Cows had access to the outdoor pasture or exercise area during 12h in daytime and could move freely from the house to the pasture or exercise area during this time. During the remaining time, they were restricted to the house.

Cows in both groups were offered drinking water in the house and were given concentrates according to milk production before experiment start. The two treatments had access to either production pasture (P) or exercise pasture (E), which were applied simultaneously in each group. On passing through a selection gate at the house exit, cows in each group were directed to their own pasture area (P or E) and had access to the area during 12 hours (06-18h) daily while all animals in both groups were restricted indoors at night-time. Silage and concentrate feeding and recording were performed at individual cow level using transponders.

Treatment E: Cows had access to the same 1-ha field (distance 200m) throughout the experiments (continuous, low sward height and low allowance, 3 kg DM/day). Group E cows received silage *ad libitum* in the house during 16h/day (14 – 06h).

Treatment P: Cows were given a new grazing area daily at a high pasture allowance (> 15kg DM per cow & day). During indoor confinement hours (18-06h), cows were offered 6kg DM silage/night. The total area used for treatment P was 5ha and the distance to pasture was 200-400m.

The results were analysed in a general linear model using the SAS programme (Ver. 9.2; SAS Institute Inc.). The model for statistical analysis of the production parameters (milk yield and milk components) contained the variable treatment (P or E) breed (SR or SH), age (primi- or multiparous) using the production parameter before experimental start as a covariate. The stage of lactation (days in milk) was tested in the model but excluded due to lack of significance. In the analysis of behaviour results the variables treatment, breed and days in milk were included in the model. The variable age and the interaction between treatment and breed were excluded from the model as they were not statistically significant for any of the response variables studied.

Results and discussion – experiment 1

The year was characterised by normal pasture conditions during the first part of the experiment, followed by dry weather during the latter part. The metabolisable energy content in silage and pasture differed between feed sources with considerably higher content of metabolisable energy in the silage offered indoors compared with the pasture, both on P and E treatments (Table 1.1). As planned, pre-grazing sward height on treatment P was considerably higher compared to E as an effect of treatment (Table 1.1).

There were no differences in production but some significant differences in behaviour between treatments as shown in Table 1.2.

Table 1.1. Content of metabolisable energy per kg dry matter (DM) in silage, production- (P) and exercise pasture (E) and sward height (cm), means (standard error).

	Experiment 2		
	Silage[2]	Prod	Exercise
Metabolisable energy, MJ/kg DM	11.2 (0.27)	9.7 (0.31)	9.4 (0.72)
Sward height, cm		11.3 (1.33)	2.6 (0.80)

[1]DM in silage 40%; [2]DM in silage 32%

With the exception of higher milk protein content for the SR breed, there was no difference between breeds with regard to the production parameters presented in Table 1.2. Furthermore, there was no interaction between treatment and breed, indicating that the responses to the grazing treatments were the same in both breeds.

There was however, a significant interaction in number of milkings per day (milking frequency) between breed and parity, with significantly higher milking frequency for primi- compared with multiparous cows of the SR Breed (2.72 and 2.50 milkings/day, respectively; $p<0.05$) while no difference was observed between primi- and multiparous cows of the SH breed (2.56 and 2.66 milkings/day).

Table 1.2. Production data for cows of the Swedish Holstein and Swedish Red breed from a grazing experiment with 12 hours access to pasture daytime, least square means (LSM), standard error (SE) and significance level for the effect of breed.

	Swedish Holstein		Swedish Red		Effect of breed[1]
	LSM	SE	LSM	SE	
Milk production data					
Milk yield,ECM[2] kg	33.4	0.82	32.1	0.62	NS
Milk yield, kg	34.1	0.79	32.3	0.59	NS
Milk fat, %	3.87	0.113	3.96	0.079	NS
Milk protein, %	3.36	0.028	3.43	0.020	*
Milk lactose, %	4.78	0.018	4.78	0.013	NS
No. of milkings/day	2.61	0.069	2.61	0.048	NS

[1] NS = not significant; P<0.10=Tend; * P<0.05; ** P<0.01; *** P<0.001. [2]ECM= energy corrected milk;

The results with regard to the effect of breed on cow behaviour are presented in Table 1.3. There was a significant (*p<0.01)* difference in the time that the cows of the two different breeds spent outdoors where cows of the SR breed spent almost one hour more time outdoors compared with the SH breed and the SR breed had a significantly (*p<0.05)* higher no of outdoor visits, 3.3 visits compared with 2.7 visits per day (Table 1.3). Furthermore, the SR breed also had a tendency (*p<0.10)* to spend more time grazing compared with the SH breed (Table 3). It is probable that the uneven number of cows of the two breeds in the experiment with only 35% animals of the SH breed made it more difficult to obtain statistically significant results with regard to differences in grazing time. More observation days may also have been beneficial in this aspect as this may have given a lower variation in the behaviour data. It is interesting to note that there was no interaction between treatment and breed in the behaviour variables indicating a similar response in both breeds to the treatments they were subjected to.

During a two week pre-period with access to the pasture area 24 hours per day and with treatments that compared exercise pasture (+ *ad libitum* silage indoors) with production pasture (+3kg dry matter silage), no significant difference in outdoor time was observed between the two breeds and no interactions between breed and treatment was observed.

Table 1.3. Behaviour data for cows of the Swedish Holstein and Swedish Red breed from a grazing experiment with 12 hours access to pasture daytime, least square means (LSM), standard error (SE) and significant level for the effect of breed.

	Swedish Holstein		Swedish Red		Effect of breed[1]
	LSM	SE	LSM	SE	
Behaviour, hours (h)					
Outdoor time[2], h	3.6	0.22	4.5	0.15	**
Grazing time[3], h	1.5	0.19	1.9	0.14	Tend
Lying outdoors[3], h	0.7	0.12	0.9	0.09	NS
Outdoor visits[2], no.	2,7	0,21	3.3	0.14	*

[1]NS = not significant; P<0.10=Tend; * P<0.05; ** P<0.01; *** P<0.001. [2]Data from 18 days of automatic recordings (N=43); [3]Data from 3 days behaviour observations (N=42).

Conclusion - Experiment 1

The overall analysis of the effect of breed on cow behaviour showed that there was no significant difference between breeds in milk yield. However, breeds differed in behaviour and the Swedish Red breed spent a significantly longer time outdoors and had a higher number of outdoor visits compared with the Swedish Holstein breed. The Swedish Red breed also had a tendency for a longer grazing time (Table 1.3).

Experiment 2 - Night time grazing with free cow traffic and batch milking – The effect of supplementary forage in the barn on cow traffic

Experiment 2 – Background

This experiment and its results, with regard to the treatments assessed, has been described in Deliverable 2.3 and also in a conference paper (Spörndly and Andersson, 2015). The focus in the present deliverable is therefore on the effects of breed and in some cases the interaction between breed and treatment.

The first automatic milking carousel, the "automatic milking rotary," AMR™, was developed by the DeLaval company. It was launched on a larger scale at the large "Euro Teir" animal husbandry fair in Hannover, Germany in 2010. It is a milking carousel where the cows are milked automatically served by a robotic arm that cleans the teats and thereafter attaches the teat cups on the cow. When milk flow decreases, teat cups are removed automatically in a similar way as in other automatic milking systems. There are a few important differences in comparison to previous AM systems in that the AM rotary can milk more cows and is therefore an interesting option for larger herds, many times herds with several hundred of cows. Recently another company, GEA, has launched an automatic milking carousel, the "DairyProQ" that can be purchased for 28-60 or possibly even 80 milking-stall units. Each stall unit has its own robotic arm. According to the company the capacity varies between 120 to 400 cows per hour depending on milk yield, milkability etc.

AM carousels can be managed in a system with batch milking or with voluntary milking. Initially, it was assumed that the AM carousel would predominantly be utilized in a voluntary milking system. This was also the case for the first AMR prototype that was tested and developed in co-operation with a group of researchers in Australia at the Faculty of Veterinary Science at the University of Sydney.

The first herd with AMR operating on a commercial basis was the Gala farm in Tasmania. In Australia and Tasmania, grazing is an important part of the cow diet and in most cases essential from an economic point of view. The Gala farm utilized the new technology using the AMR with voluntary milking during the major part of the production period. However, during the start of the calving season and towards the end of the season when the number of milking cows in the herd can be somewhat lower, batch milking has also been utilized for limited periods, showing that the system has a potential to be flexible with regard to milking and management. Thus, even though a farm with AMR generally is managed either with batch milking or with voluntary milking, it is possible for a farm to switch between batch milking and voluntary milking during the production year depending on the management set-up. In Europe however, batch milking seems to dominate the management systems for new AMR units set up. In Sweden and Germany, a number of AMR units have been sold to producers for management utilizing batch-milking. The majority of the AMR units sold in Europe have been to farms focused mainly on indoor feeding.

Since the start-up of the Swedish Livestock Research Centre Lövsta at the Swedish University of Agricultural Sciences, an AMR unit has been in place milking approximately 75% of the research milking herd. The unit has been installed for research purposes and a number of questions related to automatic milking, animal behaviour and cow traffic have been addressed in larger and smaller research projects. This AMR unit is operated with batch milking, largely for research reasons, as several of the research issues addressed at the research barn are better suited for batch milking. During the grazing season, the research herd is on pasture and questions related to grazing management need to be addressed.

For cows being milked in an AMR with a batch milking management, the issues are largely similar to the issues of pasture management of large herds in general. The increasing size of dairy herds is a major challenge that faces farmers who wish to include grazing and pasture in the feeding and management system on their dairy farm. This can be organic producers, who are required to have a high proportion of pasture in the diet of their herd during the grazing season. It can also simply be larger producers who have realized that pasture is a low-cost high quality feed that also offers health and welfare benefits at a herd level.

As herd size increases, the distance to the pasture area becomes longer and herding the animals to the pasture area and back several times per day takes time leading to higher labour costs. Furthermore, when all animals in a large herd are fetched simultaneously, cows in the herd have to spend considerable time waiting to be milked which involves stress for the cows at each milking occasion. Thus, for AMR farms with batch milking and an interest in pasture based management, it would be advantageous if it were possible to find rational systems where the labour for herding of cows between the pasture and the barn is minimized. If the cows on pasture could be allowed to return back to the barn on a voluntary basis many cows may already be in the barn ready for milking when milking is about to start, and work could be decreased. Even if part of the herd is still in the pasture area when milking starts, and therefore need to be fetched, the AMR system enables the herdsman to start the process of milking with the waiting cows while the remaining members of the herd can be brought in from the pasture while the others are being milked automatically. This can give a more even flow of cows coming to the waiting area and eventually passing into the AMR to be milked. Furthermore, if the arrival of cows to the milking facility were more evenly spaced over time, waiting for cows could be minimized and cow welfare enhanced. However, an important feature of a pasture based batch-milking AMR system must also be to ensure a high degree of pasture utilization and maintain a high production level to be economically interesting.

A grazing experiment was set up at the Swedish Livestock Research Centre (Lövsta) during the grazing season of 2014 in an AMR milking unit with batch milking. The objective was to study the effect of supplementary silage offered in the barn on cow traffic, grazing hours and outdoor time in a system where cows were herded to the pasture after milking and thereafter, could move freely between pasture and barn during night time. The objective was to test the following hypotheses regarding free cow traffic in a batch milking AMR system:

Compared with only pasture, access to supplementary silage *ad libitum* in the barn during grazing hours in this production system will:

1) give a more even passage of cows between the barn and pasture during grazing hours

2) give lower outdoor and grazing hours and fewer passages out to the pasture area.

Experiment 2 – Material and methods

The experimental design for the entire experiment is presented in table 2.1. The comparisons that form the basis of this experiment focus on a system where cows had access to the pasture area at night only. Within this night grazing system, only pasture as roughage was compared to a system where the cows are offered a free choice between pasture and indoor roughage feeding (grass silage) *ad libitum*. Periods when only pasture as roughage was offered at night were compared with periods when cows had a choice between pasture and *ad libitum* silage available in the barn. The two alternative systems were applied repeatedly and consecutively during two week periods over the experiment that lasted 10 weeks. The first week in each period was used for adaptation and the second week for measuring cow traffic between barn and pasture, synchronization in grazing hours and passages between barn and pasture, and grazing hours.

The statistical analysis of the effects on outdoor time and cow traffic in the experiment was performed using data from periods 1-5 where the same treatments were applied several times over time, using a model with repeated measurements. Only cows that were present during the entire period were used in the statistical analysis, a total of 83 cows grazing in a group of approximately 120 cows in an AMR barn with batch milking two times daily. Approximately half the cows (42 cows) were of the Swedish Red breed (SR) and remaining animals (41) were of the Swedish Holstein breed (SH). The experiment took place from 9th June until 18th August in 2014 (10 weeks). The cows were herded out to the pasture area after milking in the evening and where thereafter allowed to move freely between the pasture and the barn throughout the night.

Table 2.1. Treatment weeks, pasture access time and feeding treatment during different periods in experiment.

Period	Weeks	Pasture access, h	Feeding treatment applied	Treatment abbreviation
1	2	12 h night	Choice between pasture and silage *ad libitum* during pasture hours (night)	SP
2	2	12 h night	Only pasture as roughage during pasture hours (night)	PP
3	2	12 h night	Choice between pasture and silage *ad libitum* during pasture hours (night)	SP
4	2	12 h night	Only pasture as roughage during pasture hours (night)	PP
5	2	12 h night	Choice between pasture and silage *ad libitum* during pasture hours (night)	SP

The experimental design for the entire experiment is presented in table 2.1. The comparisons that form the basis of this analysis focus on pasture as roughage versus a system where the cows are offered a free choice between pasture and indoor roughage feeding (grass silage) *ad libitum*. The two alternative systems were applied repeatedly and consecutively during two week periods over the experiment that lasted 10 weeks. The first week in each period was used for adaptation and the second week for measuring cow traffic between barn and pasture, i.e. passages between barn and pasture, and outdoor hours. Cow passages out to the pasture area and entrances back into the barn were registered automatically with transponders and ID gates.

Grazing time was registered during periods 1-5 using HOBO® Pendant G Acceleration Data Logger (HOBO® logger) according to the methodology described and validated by Peetz Nielsen (2013) for use to estimate grazing time. The HOBO® loggers were attached on a halter fitted on 12 cows, with six cows of each breed. These loggers register the position of the head in three dimensions and were attached to a halter during the registration week i.e. second week of each period. Automatic registrations took place once every minute throughout one entire week each period and after the data was matched with outdoor periods for each cow and compiled, the grazing time was estimated from the registered position of the head using the equations presented by Nielsen (2013).

Pasture conditions during the experiment and supplements in the barn

Nutrient content of pasture and of silage offered in the barn are presented in table 2.2. The table shows that metabolisable energy content was of pasture grass was low compared with the energy content of the silage available in the barn during periods when animals had a choice between pasture and silage offered indoors.

Table 2.2. Nutrient content of pasture and silage during the experimental periods per kg dry matter (DM). Pasture analysis based on daily collection of pasture samples for analysis, silage analysis based on analysis performed on pooled samples from silo over 2 week periods.

Period	Treatment	Nutrient content of pasture per kg DM			Nutrient content of silage per kg DM		
		ME[1], MJ	CP[2], g	NDF[3], g	ME[1], MJ	CP[2],	NDF[2], g
1	SP	9.8	121	542	10.8	165	390
2	PP	9.9	109	508			
3	SP	10.5	162	449	10.4	133	551
4	PP	9.5	147	441			
5	SP	10.2	166	469	10.4	133	551

[1]ME, Metabolisable energy; [2] CP, Crude Protein; [3]NDF, Neutral Detergent Fibre

Daily sampling of pasture was performed together with daily pre-grazing sward height measurements. Sward height was 14.8cm in early season and decreased as the season progressed to 9.8cm during the last experimental period.

Animals were rotated between 11 paddocks that had been established in 2009 with a seed mixture containing 35% meadow fescue, 20% perennial ryegrass, 15% each of timothy, sweet meadow grass and white clover.

The statistical analysis was performed in with the software from SAS (Statistical Analysis System, SAS version 9.2 SAS Inst. Inc). The statistical model was a mixed model with “animal*treatment” as repeated subject. The model for milk yield contained the class variables treatment, breed and age (primi- and multiparous) and the continuous variable days in milk (at experimental start).

The statistical model for the analysis of the effect of breed on the behaviour variables outdoor time and outdoor visits was analysed in a mixed model with animal*treatment as repeated subject and the model included the effect of the continuous variable experimental week and the class variables treatment, breed, age (primi- vs multiparous cows) with interactions treatment*week and treatment*age.

The analysis of the data from the HOBO® loggers estimating grazing time included only 10 of the 12 animals fitted with the loggers as data from 2 animals had to be excluded from the analysis due to technical problems that gave extremely high grazing hours which strongly diverged from all other data. The data from these cows were therefore regarded as outliers. With 10 cows in the statistical analysis and repeated measurements of these cows during the five periods, the statistical model for analysing grazing time did not allow as many variables and interactions in the model due to limited degrees of freedom. Therefore, the model for the analysis of grazing time included the continuous effect of experimental week and the class effects treatment, breed, and the interaction between treatment and experimental week.

Experiment 2 – Results effect of breed on milk yield and animal behaviour

A significant effect of breed was observed in the results with a higher milk production for the Swedish Holstein breed (Table 2.3). There was a tendency (*($p<0.07$)* for a higher milk yield (+0.2kg milk/day) for the treatment with supplementary silage indoors (SP).

No interaction between breed and treatment was observed in this dataset indicating that animals of both breeds had a similar response in milk production and behaviour to the treatments in the experiment. No significant effect of age was observed in this dataset.

The effect of breed was not significant for any of the behaviour variables as shown in table 2.3. However, a tendency for a higher number of outdoor visits for the Swedish Red breed was observed.

Table 2.3. Analysis of the effect of breed on milk yield, outdoor time and number of outdoor visits in experiment 2, least square means (LSM), standard error (SE) and statistical effect of breed. Number of animals in analysis N=83 with the exception of grazing time where N=10.

	Swedish Holstein		Swedish Red		Effect of breed[1]
	LSM	SE	LSM	SE	
Production					
Milk yield, kg	31.4	0.99	28.2	0.98	*
Behaviour					
Outdoor time, h	6.8	0.20	7.0	0.20	NS
Outdoor visits, no	1.3	0.03	1.4	0.03	Tend
Grazing time	2.8	0.37	3.0	0.42	NS

[1]NS = not significant; P<0.10=Tend; * P<0.05; ** P<0.01; *** P<0.001.

Conclusions – experiment 2

The Swedish Holstein had a significantly ($p<0.05$) higher milk yield (+11%) compared with the Swedish Red breed during the experiment. The difference was slightly higher than the average difference between the breeds in the official milk recording control system last year, where the milk yield of the Swedish Holstein was reported to be 7.5% higher than the Swedish Red breed (Växa Sverige, 2015). There was no interaction between treatment and breed indicating that the two breeds responded in a similar manner to the treatments they were subjected to in the experiment. Furthermore, there was no significant difference between the two breeds in any of the behaviour variables studied. The results indicate that there are no major differences between breeds in the response to the free cow traffic with different amounts of supplementary silage in the barn.

Experiment 3 – Behaviour of cows in an automatic milking system with morning and evening access to the pasture area

H. Kismul and E. Spörndly

Experiment 3 - Background

This experiment was financed by the Swedish Farmers Foundation for Agricultural Research, and not within the framework of the EU project AUTOGRASSMILK. However, the project has been initiated and granted funding due to interesting results obtained in the AUTOGRASSMILK project and the experiment described below and the results are highly relevant to the question of breed in relation to AM systems combined with grazing.

The experiment was carried out in 2015 and the complete production results have not yet been analysed. However, the statistical analysis of the animal behaviour observations in the experiment have been completed and can thus contribute to the evaluation of the effect of breeds in systems where automatic milking is combined with grazing, in this case the comparison between the Swedish Holstein and the Swedish Red breed.

The Swedish law requires all cows to go out onto pasture in the summer, with access to a pasture area during at least 6 hours daily. Many farmers regard pasture as a problem and therefore it is common to offer the cows an exercise/recreation pasture, i.e. a small outside pasture area at a high stocking rate and combine this with full *ad libitum* feeding of silage indoors throughout the grazing period. Other farmers see the benefit of production pasture and therefore include pasture in the diet up to approximately 25-30% of the estimated dry matter intake of the cow. An experiment was performed within a system of part time grazing to compare the behaviour of cows on production pasture compared with exercise/recreation pasture for cows. Earlier, this question has been studied in a daytime grazing system (see experiment 1 above). The present experiment has been performed to compare exercise and production pasture in a system with morning and evening access to pasture (4.5 + 4h) daily. It was hypothesized, that compared with daytime access to pasture where time spent outdoors and grazing was comparatively low (experiment 1) a system with morning and evening access to pasture would be better adapted to the natural behaviour of cows. Behaviour studies performed in a natural environment, without the interference of human management, have shown that cattle often have an active period of grazing in early mornings and evenings (Kilgour, 2012). The objective was thus to find a system where animals would spend more time outdoors and more time engaged in active grazing, thus utilizing the time of pasture access more efficiently for grazing and locomotion.

Experiment 3 – Material and methods

The experiment was performed to study the outdoor and grazing behaviour of dairy cows in a part time grazing system where cows have access to the pasture area during 4.5 hours in the morning (06-10.30) and 4 hours in the evening (16-20 hours), a total of 8.5 hours per day. A total of 41 cows, with 22 cows of the SH breed and 19 of the SR breed, completed the 7 week experimental period that lasted from June 8th until July 27th 2015. Cows were evenly distributed over the two treatments with 20 cows on the treatment where cows had access to exercise pasture and 21 cows on the treatment with production pasture (see below). The 41 experimental cows were kept in a barn with around 60 cows to ensure that the number of cows in the system were representative of a normal Swedish farm with one milking robot. The cows were grouped according to age (primi- and multiparous) and breed (SH and SR) and within these four groups, cows were randomly distributed over the two treatments, thus obtaining treatment groups that were comparable with regard to age and breed. Both treatment groups had access to the outdoor area between 06-10.30 and 16-20 hours daily and each cow received a concentrate supplement according to the milk yield before pasture let-out, assuming a total forage (silage or pasture+silage) intake of 12kg DM daily and assuming a standardized weekly decrease in milk production of 0.125kg and 0.33kg for primi- and multiparous cows, respectively, according to the Swedish standardized lactation curves for the SH breed as presented in the Swedish Norfor feeding system (Volden, 2011).

The cows in the exercise pasture group (Treatment E) had daily access to the exercise area at a stocking rate of around 25 cows per ha in a continuous system. They had *ad libitum* access to silage in the barn throughout the day and night period.

Cows on the production pasture treatment (Treatment P) were offered a new pasture area daily at an allowance of 15kg DM pasture per cow and day. During the night hours when cows were restricted in the barn (20 - 06h) the cows on treatment P had access to 6kg DM silage per night. During daytime hours cows were assumed to eat around 6 kg DM pasture during the 8.5 hours (06-10.30 + 16-20h) when cows had access to the grazing area.

Experiment 3 – Results

The analysis of animal behaviour in the experiment showed no significant differences between breeds for the total time spent outdoors or the time they spent lying down outdoors (Table 3.1). Furthermore, no overall effect of interaction between breed and treatment was seen for these behaviours. The analysis of the time that cows spent in the cow lane was not normally distributed, therefore, this variable could not be statistically analysed and only ordinary means can be reported, with cows of the SH and SR breed spending 1.3h and 1.5h per day in the cow lane, respectively.

However, there was a significant interaction between breed and treatment on the grazing time. No significant difference between breeds was observed on the treatment with the exercise pasture while on the production pasture, cows of the SR breed spent significantly more time grazing compared with cows of the SH breed (Table 3.1).

Table 3.1. Outdoor time, grazing time and time spent lying outdoors of cows of the Swedish Holstein and Swedish Red breeds on the treatments with Exercise pasture and Production pasture in a grazing system with access to the outdoor area during a total of 8.5 hours daily (06-10.30 and 16-20 h). Least square means with standard error in parenthesis and the overall significance of breed and of the interaction breed*treatment (N=41).

	Swedish Holstein		Swedish Red		Effect of breed[1]	Effect of interaction[1]
	Exercise	Production	Exercise	Production		
Outdoor time, h	2.5[a] (0.20)	5.3[b] (0.17)	2.5[a] (0.18)	5.6[b] (0.21)	NS	NS
Grazing time, h	0.6[a] (0.10)	3,5[b] (0.08)	0.5[a] (0.09)	4.0[c] (0.11)	*	**
Lying outdoors, h	1.4[a] (0.16)	1.8[ab] (0.13)	1.2[ab] (0.15)	1.6[b] (0.17)	NS	NS

[1]NS = not significant; P<0.10=Tend; * P<0.05; ** P<0.01; *** P<0.001.

Overall conclusions

The results from experiments 1-3 above are not conclusive. In each of the experiments the comparison between the Swedish Holstein and the Swedish Red breed indicate that there are no major differences in the performance of the two breeds in an AM system combined with grazing. The Swedish Holstein breed has a higher milk yield in the Swedish official control system and this difference in production level has also been found as a significant difference between breeds in experiment 2. In experiment 1, the pre-experimental milk yield was used as a covariate in the model and therefore, no difference between the breeds in production level was found, thus indicating that both breeds reacted in a similar way with regard to milk production level to the treatments imposed. However, throughout the three experiments analysed here, there have been indications that the Swedish Red breed demonstrates a more active outdoor and grazing behaviour, with longer outdoor hours (sign in exp 1), higher number of outdoor visits (sign in exp. 1; tendency in exp. 2) and longer grazing hours (tendency in exp. 1; sign in exp. 3). However, consistent benefits of the slightly more active grazing behaviour, such as higher milk production, have been absent. It is possible that this may partly be due to the comparatively high level of supplementary feeding in experiments 1-3, where the proportion pasture in the diet on a DM basis was low and never exceeded around 25%.

References

Kilgour, R.J. 2012. In pursuit of ”normal”: A review of the behaviour of cattle at pasture. Applied Animal Behaviour Science 138 (1-2): 12-17.

KRAV, 2015. Standards for KRAV certified production 2015 versiion. The KRAV association. http://www.krav.se/krav-standards (November 2015).

Peetz Nielsen, P. 2013. Automatic registration of grazing behaviour in dairy cows using 3D activity loggers. *Applied Animal Behaviour Science*.148:179– 184

SJV (Swedish Board of Agriculture) 2014. Livestock in June 2014. Official Statistics of Sweden (SOS), Statistical Reports JO 20 SM 1403, Swedish Board of Agriculture, http://www.jordbruksverket.se (Sept 23, 2015)

SJV (Swedish Board of Agriculture) 2015a. Number of cattle in December 2014 – Annual monthly statistics, Official Statistics of Sweden (SOS), Statistical Reports JO 23 SM 1501, Swedish Board of Agriculture, http://www.jordbruksverket.se (Sept 23, 2015)

SJV (Swedish Board of Agriculture) 2015b. Animal products – Annual monthly statistics, Official Statistics of Sweden (SOS), Statistical Reports JO 48 SM 1508, Swedish Board of Agriculture, http://www.jordbruksverket.se (Sept 23, 2015)

SJV (Swedish Board of Agriculture) 2015c. Organic animal production, 2014, Official Statistics of Sweden (SOS), Statistical Reports JO 27 SM 1501, Swedish Board of Agriculture, http://www.jordbruksverket.se (Sept 23, 2015)

Spörndly, E. and Andersson, Å. 2015. Effect of indoor silage feeding on pasture time in a batch milked automatic milking rotary system. In: Proc. 18th Symp. Of the European Grassland Federation, Wageningen, The Netherlands, 15-17 June 2015. Eds: A. van den Pol-van dasselaar, H.F.M. Aarts, A. De Vliegher, A. Elgersma, D. Reheul, J.A. Reijnefeld, J. Verloop & A. Hopkins. Grassland Science in Europe Vol 20, Grassland and Forages in high output dairy farming systems, pp 125-127.

Spörndly, E., Andersson, S., Pavard, N. & Le Goc, S.. 2015. Production pasture versus exercise and recreation pasture for cows in automatic milking systems. In: Proc. 18th Symp. Of the

European Grassland Federation, Wageningen, The Netherlands, 15-17 June 2015. Eds: A. van den Pol-van dasselaar, H.F.M. Aarts, A. De Vliegher, A. Elgersma, D. Reheul, J.A. Reijnefeld, J. Verloop & A. Hopkins. Grassland Science in Europe Vol 20, Grassland and Forages in high output dairy farming systems, pp 125-127.

Volden, H. 2011. NorFor – The Nordic feed evaluation system. EAAP publication No. 130. Editor: Harald Volden. Wageningen Academic Publishers, the Netherlands, 2011.

Växa Sverige, 2015. Kokontrollen 2014/2015. Nästan tio ton per kossa.(In Swedish) Latest data from the official cow control system 2014/2015.Swedish Dairy Farmers magazine “Husdjur” no. 10, 62-63.