# Investigating the effect of grazing soybean on voluntary cow traffic and behaviour in a pasture-based automatic milking system

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## Abstract
A total of 194 cows were randomly assigned into one of two treatment groups (Group A and cross over design Group B), with groups balanced for milk yield, days in milk (DIM) and parity. Group A grazed soybean in the first period and pasture in the second, while Group B grazed pasture followed by soybean. The herd was managed with controlled cow traffic and milked by a prototype Robotic Rotary (RR; Automatic Milking Rotary (AMR™), DeLaval, Tumba, Sweden). In controlled cow traffic cows pass one-way gates and automatic drafting gates were they will be recognized and sent to the milking unit or straight to the feeding area if the time since the last milking was less than the minimum milking interval. The trial consisted of two periods of seven days; four habituation days and three trial days. Before the habituation days all the cows had two training days on soybean. Between 0900 and 1500, cows had access to their treatment paddock following milking. Throughout the remainder of the day, treatment groups grazed shared paddocks as a combined herd. Behavioural observations in both treatment paddocks were recorded every 15 minutes starting at 0900 using scan sampling. Behaviours were recorded as: standing idle, lying idle/resting, walking, grazing, standing ruminating, lying ruminating and 'other' behaviour. Grazing, lying resting and standing were used for the analysis of cow behaviour. Day, period, cow number, lactation, group, treatment, DIM, yield and the milking interval were also considered in the analyses. A linear mixed model was used to analyze the cow traffic data, while summary statistics were used to describe trends in the behavioural data. Cows tended to graze more in the soybean paddock compared to pasture. They also grazed more during the morning compared to the afternoon. There was a difference in milking interval between cows grazing soybean and grass, where it was shorter when cows grazed soybean, however the difference was not significant. Lactation, DIM and yield had a significant effect on milking interval. Results indicated that grazing soybean did not act as an incentive to increase voluntary cow traffic despite a small difference in milking interval being detected.

## Samenvatting
In totaal zijn 194 koeien verdeeld over twee behandelingsgroepen (Groep A en B) aan de hand van pariëteit, lactatiestadium en melkgift. Groep A heeft soyaboonplanten gegraasd in de eerste periode en gras in de tweede, terwijl Group B eerst gras gegraasd heeft en vervolgens soyaboonplanten. Er vond controlled cow traffic plaats en de koeien werden gemolken door een prototype van een automatisch roterende melkrobot (Automatic Milking Rotary (AMR™) DeLaval, Tumba, Zweden). Bij controlled cow traffic passeren koeien eenrichtingspoorten en automatisch sorterende poorten waar ze geïdentificeerd worden. Vervolgens worden ze naar de melkrobot gestuurd, of direct naar de voederplaats wanneer de tijd sinds de laatste melkbeurt minder is dan het minimum melkinterval (4 uur). Het onderzoek bestond uit twee periodes van zeven dagen; vier gewenningsdagen en drie onderzoeksdagen. Voor de gewenningsdagen had de hele kudde twee trainingsdagen in een soyaboonweide. Tussen 9:00 en 15:00 uur hadden de koeien na het melken toegang tot hun 'behandelingsweide'. Gedurende de rest van de dag grazen de koeien in gezamelijke weiden als een gecombineerde kudde. Elke 15 minuten vanaf 9:00 uur werd elk uitgevoerd gedrag opgeschreven m.b.v. de scan sampling methode. Het gedrag werd geclassificeerd als: staan, liggen/rusten, lopen, grazen, staand herkauwen, liggend herkauwen en ander gedrag (overig). Grazen, liggend rusten en staan werden gebruikt voor het analyseren van het gedrag. Dag, periode, koenummer, lactatie, groep, behandeling, lactatiestadium, melkopbrengst en het melkinterval werden ook meegenomen in de analyse. Met behulp van een lineair mixed model zijn de koebewegingen geanalyseerd en er is gebruik gemaakt van summary stats om het gedrag te analyseren. De trend is dat koeien meer grazen in de weide met

soyaboonplanten vergeleken met een weide met gras. Ze grazen ook meer gedurende de morgen dan tijdens de middag. Er is een verschil in het melkinterval tussen koeien die soyaboonplanten grazen en koeien die gras grazen. Hoewel het melkinterval korter is wanneer koeien soyaboonplanten grazen, is dit verschil niet significant. Lactatie, lactatiestadium en melkopbrengst hebben wel een significant effect op het melkinterval. De resultaten geven aan dat het grazen van soyaboonplanten niet als een lokmiddel werkt om vrijwillige koebewegingen te verhogen ondanks een klein waargenomen verschil in het melkinterval.

## Introduction

Previous research has shown that soybean is preferred over other species by grazing dairy cattle.[4] Soybean offers a different palatability to the standard pasture species found in the mid-east region of Australia (predominantly Kikuyu (Pennisetum clandestinum) in summer and perennial Ryegrass (Lolium perenne) in winter), and is thought to be more desirable as a grazing forage than the commonly grown grass species.[4] Voluntary cow traffic (where cows move around the farm system with little or no human intervention) is commonly used in pasture-based systems operating automatic milking systems (AMS), to encourage cows to move to different parts of the farm, including the dairy. Therefore the use of incentives is necessary to encourage cows to traffic around the farm.

### *Automatic milking systems*

Despite AMS being widely used in Europe, there are only a relatively small number of AMS farms (n=20, K. Kerrisk, University of Sydney, *pers. Comm.,* June 2013) currently operating in Australia. There are two major differences between Australian and European farms: herd size and the way the cows are managed. In Australia, farms are predominantly pasture-based with average herd sizes in excess of 250 cows, while in Europe the herds are generally smaller and tend to be kept indoors during a large period of the year.[8]

Traditionally, AMS was either a single-stall or multi-stall system. In single-stall systems, one integrated robot is used. In the multi-stall system, there can be up to five stalls with a mobile robot device moving from one stall to the next to attach the teat-cups. To make automatic milking systems more suitable for the Australian farms, a Robotic Rotary (RR; DeLaval Automatic Milking Rotary, AMR™) was developed by DeLaval in collaboration with Australia's FutureDairy project and a prototype was installed at the Elizabeth Macarthur Agricultural Institute (Camden, New South Wales) in 2009. While the single-stall systems are best suited in herds smaller than 300-400 cows, the RR can be used with herd sizes between 300 and 800 cows.[6,7]

The Camden prototype RR had sixteen milking points; whilst the commercial RR has 24. It is possible to have two to five robots, depending on the required throughput capacity. A five robot installation would have two robots for teat washing, two for cup attachment and the fifth for disinfection of the teats after milking. In a two robots installation, one is used to clean the teats and the other one for cup attachment.[6,7] Teat washing is an important part of AMS, where it assists in preventing contamination of the milk and minimizing the risk of transferring udder pathogens. There are different ways to clean the teats: sequential cleaning by brushes or rollers, cleaning with water in the same teat cup as used for milking, and cleaning by a separate 'teat cup-like' device (as is the case in the RR).[8]

The prototype RR has an internal herringbone rotary platform with cows angled at 30 degrees. The robotic arms accessed the udders from the side (between the front and rear legs).[6,7]

Single-stall robotic boxes are able to milk six to ten cows per hour. In comparison, the RR is estimated to be capable of milking up to 50 cows per hour with two robots. This can be increased to up to 90 cows an hour with five robots (two attachment robots). Whilst there are several factors influencing capacity, it is largely dependent on the rate of cow movement onto the RR platform.[6,7]

As with any AMS, the farmer still needs to do certain milking-related tasks when operating the RR. These include: activating the washing system, changing filter socks and rubber-ware, attending to alarms, managing abnormal milk cows (e.g. antibiotic and colostrum cows) and monitoring individual cow performance and cow traffic. As mentioned later in this report, abnormal milk cows have to be batch milked (as a group) prior to the system wash in order to clean out the milk lines before continuing to harvest commercially acceptable milk.

Automatic milking systems rely upon voluntary cow traffic, and the correct placement of incentives to motivate cows to move around the farm system. The most effective incentive for voluntary cow traffic is food, and could be in the form of concentrate, supplementary feed (such as silage) or a fresh paddock allocation if the farm is pasture-based.[8,13]

There are different systems to guide cow traffic. In 'forced cow traffic' the feeding area can only be reached after passing through the milking unit. In 'controlled cow traffic' cows have to pass through one-way gates and electronic drafting gates, where they will be recognized and sent to the milking unit or straight to the feeding area if the time since the last milking was less than the settable minimum milking interval. In 'free cow traffic' cows can move to the feeding area freely, however they can only get concentrate in the robotic unit.[8]

Research has shown that the distance from the paddock to the dairy influences the milking frequencies and the milk yield. Danish research showed that cows in a paddock 50 meters from the barn had a higher milk yield and a shorter milking interval compared to cows in a paddock 260 meters from the barn. The cows had the opportunity to go to the paddock 24 hours per day and cow traffic was controlled.[16,17] Other researchers concluded that there is a limited effect in milking frequencies and milk yield if the distance between the barn and the pasture is 400 to 500 meters.[1,8,13,15,17] Furthermore, it has been found that there was no difference in milking frequencies and milk yield if the paddock is less than 800 meters from the farm (N. Lyons, *pers. comm.*, June 2003), although cows visited the dairy less frequently and had a lower milk yield if the paddock was more than 800 meters from the dairy.

### ***Objectives and hypotheses***

The main aim of this trial was to investigate the potential use of soybean as an incentive for encouraging increased voluntary cow traffic in a pasture based AMS. Within this overriding aim, the following objectives were addressed:

a) Understanding how cows move from stale breaks into a fresh soybean break (compared to a fresh pasture break (predominantly ryegrass) of similar walking distance from the dairy).
   a. The hypothesis is that cows "expecting" soybean would move more quickly through the system in order to get to their soybean break while cows expecting pasture would not move as quickly.
b) Understand how cows graze the soybean paddock.
   a. The hypothesis was that cows would spend less time resting and more time grazing when offered a more palatable forage.

Concurrently, research was conducted investigating the potential use of soybean as a forage crop in pasture-based AMS.

## Materials and methods

### ***Farm changes and paddock set-up***

The entire milking herd at the Camden AMS Farm was included in this trial, totaling 194 dairy cows. As is typical for an Australian dairy farm, cows were managed in a pasture-based system, whereby cows are kept outside throughout the entire year. The herd was managed with controlled cow traffic, as described previously, with a modified two-way grazing practice (two pasture allocations per 24 hour period) employed. This modified practice included a 'night' paddock allocation (predominantly grazing kikuyu) and three distinct 'day' paddocks (Table 1). After 0900, cows were drafted automatically at the dairy following milking (based on treatment groups) to their allocated treatment paddock (either pasture or soybean). From 1500 onwards, all cows exiting the dairy were sent to a common kikuyu day paddock until the opening of the night paddock at 2100 (Table 1). The minimum milking interval at the farm is four hours.

Table 1: Availability, allocation and management of paddocks throughout the study period

| Paddock | Active access | Fetching | Total possible time in paddock | Targeted allocation~ | Percent of Daily allocation |
|---|---|---|---|---|---|
| **Night Kikuyu** | 2100-0900 | 0700 | 22hr | 8kg/c | 35% |
| **Day Pasture Treatment** | 0900-1500 | 1700 | 8hr | 4kg/c | 18% |
| **Day Soybean Treatment** | 0900-1500 | 1700 | 8hr | 4kg/c | 18% |
| **Common Day Kikuyu** | 1500-2100 | 0700 | 16hr | 4kg/c | 18% |
| **Concentrate** | | | | 6 kg/c | 27% |

~ Allocated per cow per day, with a total target intake of 22Kg per cow per day

Paddocks were grazed in strips using temporary electric fences (12V). To determine the width and shape of the strip, the pre-grazing covers were calculated daily. The same dry matter allocation was targeted in both treatment paddocks, with a targeted daily feed allocation of 4 kg/cow per treatment paddock (Table 1). This made the conditions in the paddock comparable to each other. Strip-grazing made it easier to do the observations without entering the paddock and disturbing the cows. The soybean paddock averaged 0.16 hectares and the pasture 0.14 hectares. The paddocks were within 800 meters from the dairy; the soybean paddock was at 613m and the grass paddock at 428m from the dairy. Concentrate and Partial Mixed Ration (PMR) were available at the dairy following milking in a feeding area.

Apart from changes as outlined above and in Table 1 (to paddock layout, active access times and pasture allocations), other on-farm activities (milking abnormal milk cows, encouraging cows onto the RR prior to milking abnormal milk cows and a system wash, and fetching cows from the paddocks) were as per normal practices. The abnormal milk cows (colostrum cows, cows with a high cell count and cows on antibiotics) were milked on a daily basis at approximately 0600 and 1800. The milking of the abnormal milk cows was followed by a machine wash and aimed to be completed by 0730 and 1930 respectively. All cows remaining in the pre-milking yard were encouraged onto the platform for milking to clear the path for the abnormal milk cows. These cows were recorded with time and date. The commencement of encouraging cows onto the RR depended on the number of cows in the pre-milking yard, with an estimated completion time of 0600 and 1800 (to allow for the milking of abnormal milk cows). Fetching occurred as per Table 1.

### *Animals*

The 194 dairy cows were randomly allocated into one of two treatment groups (Group A or Group B), with groups balanced for milk yield, days in milk (DIM) and parity. A crossover design was used (cows allocated Soybean in period 1 were allocated pasture in period 2, and vice-versa), along with providing training and habituation periods prior to data collection (Table 2).

Table 2: Summary of trial design and allocation of treatments per group.

| Days | Period | Activity | Group A | Group B |
|---|---|---|---|---|
| **2** | Prior to study | Training on Soybean | Soybean | Soybean |
| **4** | 1 | Habituation | Soybean | Kikuyu |
| **3** | 1 | Data collection | Soybean | Kikuyu |
| **4** | 2 | Habituation | Kikuyu | Soybean |
| **3** | 2 | Data collection | Kikuyu | Soybean |

Prior to commencing the study, the entire herd was given two days of training on the soybean crop to become exposed to/familiar with soybean as the herd was naïve to grazing soybean as forage. Group A grazed soybean in the first period and pasture in the second, while Group B grazed pasture followed by soybean (Table 2). Group A was fitted with colored collars to visually differentiate them from group B to assist in farm management. The colored collars also made it possible to easily recognize any cows from Group A which had managed to be drafted to the wrong paddock and vice-versa.

During the initial training period, cows were fetched from the Night paddock at approximately 0800, milked and drafted to the soybean allocation. This additional management was necessary to ensure that all the cows were milked and gained access to soybean before the active access period finished (at 1500) in order to ensure that the whole herd had been exposed to soybean prior to the commencement of the study, and were familiar with the required gate passages and grazing routines.

The habituation periods were four days in duration. During these days, farm activities (pushing cows in the dairy and fetching them from the paddocks) were consistent with routines and management practices of the experimental/data collection period. The aim of the habituation period was to allow the cows to settle into their treatment prior to data collection.

During the data collection days, behavioral observations were carried out and information on cow traffic was captured through electronic records of automatic drafting gate passings.

## Paddocks

### *Pasture*

On the Elizabeth Macarthur Agricultural Institute (Camden farm), and on many other farms in Australia, there are two predominant pasture species throughout the year. In winter, the predominant species is Ryegrass (Lolium perenne) which is less water efficient and declines in growth in late spring when the growth of the summer grass, Kikuyu (Pennisetum clandestinum), commences.[2]

Kikuyu grass naturally grows on the highland plateau of east and central Africa. Seed of Kikuyu was introduced in Australia in 1919 from Congo.[10] Kikuyu has become endemic along most of the east coast and in irrigated pastures in the south west of Western Australia since then. Now it is one of the most important pasture species for dairy production in Australia.[2]

Kikuyu must be sown when the temperature is above 15°C to give the seeds the chance to germinate. The best time for sowing is in early autumn. Grazing and fertilizer management are very important to maximize energy density.[2]

Cows grazing kikuyu can produce up to 14-15 L of milk per cow per day and this can be more if energy dense supplements, such as cereal grains, are available. The dry matter digestibility is 53 to 74 per cent.[2]

Feeding additives with concentrates are necessary to correct sodium, phosphorus and calcium deficiencies in the Kikuyu. With good management the metabolisable energy in Kikuyu can be up to 9 MJ/ Kg DM. Proper fertilization with nitrogen provides adequate protein content in the Kikuyu.[2]

### *Soybean (Glycine max)*

Wild soybeans were discovered in northeastern Australia in 1770 and in 1879 the first domesticated soybeans arrived in Australia. Soybean provides high quality forage for growing and fattening stock and for lactating dairy cows. The later maturing types are preferred for grazing.[12]

Soybean is a good crop to use in coastal areas; it grows well on loams, clay loams and self-mulching clay soils. The best time to saw soybean is from mid-November to December. For successful germination the soil temperature needs to be above 13°C, but for a rapid growth soil temperatures above 25°C are optimal. Seed must be inoculated before sowing to ensure good nodulation and nitrogen fixation in the soil.[3,12]

Soybean is vulnerable to cutworm, wireworm, grass blue butterfly, the lesser armyworm and the heliothis caterpillar from sowing until about four weeks after seedling emergence. Sclerotinea stem rot is also a problem especially in fields where crop rotation with resistant crops is not used.[11]

The digestibility is 50 to 56 percent on a whole-plant basis, although the leaf is more highly digestible (60 to 65 per cent digestible dry matter). This digestibility is visible with cow preference for leaves over stems clearly observed, with cows consuming 80 per cent more leaves than stems. The metabolisable energy is similar to that of Kikuyu namely 9,4 MJ/ kg DM for the whole plant.[12]

***Recording data***

Apart from behavioral observations, a variety of data was collected during this trial both manually and electronically. All the farm activities were recorded manually during the six days of data collection. All fetchings were recorded, including the time of fetching and the number of animals fetched. The animal numbers of the cows that were encouraged on to the platform, including the time, were also recorded. The duration and timing of any robotic factors (including down-time for maintenance, breakdowns and system washes) that may have impacted on voluntary cow traffic were recorded.

Electronic data from smart gate passings (automatic drafting gates) and milkings were collected from the computer in the farm office using DelPro™. DelPro™ is an integrated dairy management system made by DeLaval, and collects/stores information and reports on (but not limited to) milk yield, feeding data and reproduction.[20]

***Behavioural observations***

Direct observations were conducted in the paddock to gain a greater understanding of the cow behaviour in the soybean paddock in comparison to the pasture paddock.
There were two observers in each paddock from 0900 until 1700 (when cows were fetched from treatment paddocks). Observers were scheduled to conduct four hour shifts (either 0900-1300, or 1300-1700).

Cow entry and exit traffic was recorded manually. Each entry and exit event was recorded with a time stamp and the cow ID. A cow was considered in the paddock when both front legs had passed through the gateway and was considered to be out of the paddock when both front legs had passed through the gateway into the lane. The time was recorded using a stop watch that was synchronized with the time in the dairy.

Scan sampling was used to record the behaviour of all cows in the grazing allocation at 15 minute intervals. A Dictaphone was used to record the behaviour of the cows (but not the individual cow ID) as the observer walked along the length of the allocation (external to the allocation itself), always commencing observations at the entrance to the paddock. After each scan sampling session, the audio record was played back and a tally of recorded behaviours was generated. Behaviour was classified as: standing idle, lying idle/resting, walking, grazing, standing ruminating, lying ruminating and 'other' behaviour (see appendix for further details).

**Statistical/Data analysis**

***Cow behaviour***

All the cow behaviours were entered in Excel (version 2007). The proportion of observations recorded for each behavior was determined to estimate the time cows spent displaying each activity. The proportion of time spent in each behavior (lying, standing and grazing) was calculated for the morning (0900-1300), afternoon (1300-1700) and the day as a whole (0900-1700). Only lying, standing and grazing were analyzed in this way. For the analysis of the cow behaviour summary stats were used.

***Cow traffic***

Animal number, lactation, DIM, yield and cow traffic (movement through automatic drafting gates) were obtained from DelPro™.

Day (one to six), period (one or two), group (A or B) and treatment (soybean or pasture) were added to the data set, and the waiting time and milking interval were calculated with Excel. The waiting time (in hours:minutes:seconds) is the time from entering (via an automatic drafting gate) the barn until the milking. The milking interval (in hours, minutes and seconds) is the time between two consecutive milkings (time since the last milking until the current milking).

Lactation, DIM and yield were categorized because the Scatterplots showed no linear relationship. Lactation was categorized by comparing the average yield per lactation and grouping the lactations with similar average yields.  Lactation two, three and four have similar average yields and starting at lactation five the average yield is going down again and stays lower, except for lactation eleven. There were only a few cows in lactation eleven compared to the other lactations. The yields were relatively high, making the average yield higher than the other average yields. The following categorizations were made: categorized lactation (Catlactation) one is lactation one, Catlactation two consists of lactation two, three and four and Catlactation three is made up of lactations five and higher (Table 3).

A classification for lactation status ('DIM') such as used by CRV was used to categorize DIM, creating five categories.[19] Cows with less than 60 days in milk belong to categorized DIM (CatDIM) one, between 61 and 120 days to CatDIM two, cows between 121-200 days are assigned to CatDIM three, 201 to 305 days to CatDIM four and in CatDIM five are the cows that are longer than 305 days in milk.

To classify yield, the average yield for all cows in a given lactation was calculated to allow individual cows to be categorized as yielding either above or below the calculated average yield for the relevant lactation. The animals were classified as above average (1) or below average (0). The categorized factors are described in Table 3.

Table 3: Categorization of lactation, DIM, yield

| Lactation | Catlactation | Yield (kg) | Catyield | DIM | CatDIM |
|---|---|---|---|---|---|
| **1** | 1 | **9.12** | 0/1 | **<60** | 1 |
| **2** | 2 | **11.82** | 0/1 | **61-120** | 2 |
| **3** | 2 | **12.53** | 0/1 | **121-200** | 3 |
| **4** | 2 | **13.58** | 0/1 | **201-305** | 4 |
| **5** | 3 | **12.18** | 0/1 | **>305** | 5 |
| **6** | 3 | **9.43** | 0/1 | | |
| **7** | 3 | **11.81** | 0/1 | | |
| **8** | 3 | **9.20** | 0/1 | | |
| **11** | 3 | **19.88** | 0/1 | | |

A linear mixed model was used to investigate the effects of the explanatory factors on the dependent variable (Milking interval). A factor is considered significant at the 0.05 level. Period, day, group, treatment, Catlactation, CatDIM and Catyield were the factors and animal number was included as a random effect. Lactation, yield and DIM were covariates. The model of best fit was calculated by looking at Akaike's Information Criterion (AIC) and finding the model with the lowest AIC value. A Q-Qplot, Scatterplots and Boxplots of the residuals were made to check the assumptions underlying linear regression.

## Results

### *Cow behaviour*

The hypothesis was that cows would spend less time resting and more time grazing when offered a more palatable forage. As mentioned above, only grazing and resting behaviours (standing and lying resting) were looked at to answer the hypothesis.

On average the first cows arrived in the paddock between 0930 and 1000. During four out of the six trial days, there were more cows in the soybean paddock than the pasture paddock. On average the cows stayed 2 hours and 49 minutes in the pasture and 3 hours and 29 minutes in the soybean paddock. On the second day almost all the cows in the pasture treatment left the paddock around 1530.

Figures 1-5 show the proportion of each behaviour as a percentage of the total behaviours observed, along with the treatment.

In Figure 1, a trend in the time cows spent grazing between treatments was apparent, where cows spent more time grazing in the soybean than the pasture. Cows in the soybean actually grazed more, on average 8.4 kg/DM/day, while the cows in the pasture only grazed 4.7 kg/DM/day. The targeted daily feed intake was calculated for 90 cows, that's why it was possible that cows grazed more than the allocated 4 kg/DM/day. During the first three days of the trial cows in the soybean paddock also spent less time standing and lying, and more time grazing, when compared to the cows in the pasture. The differences between the treatment groups are smaller during the second period. During the last day of the trial there are more cows grazing in the pasture compared to the soybean paddock.

When looking at behaviours on a per-group basis (Group A in Figure 2, and Group B in Figure 3), cows spent more time grazing when in the soybean paddock compared to the pasture paddock. Group A was found to spent more time (on average) grazing compared to Group B, during the whole trial.

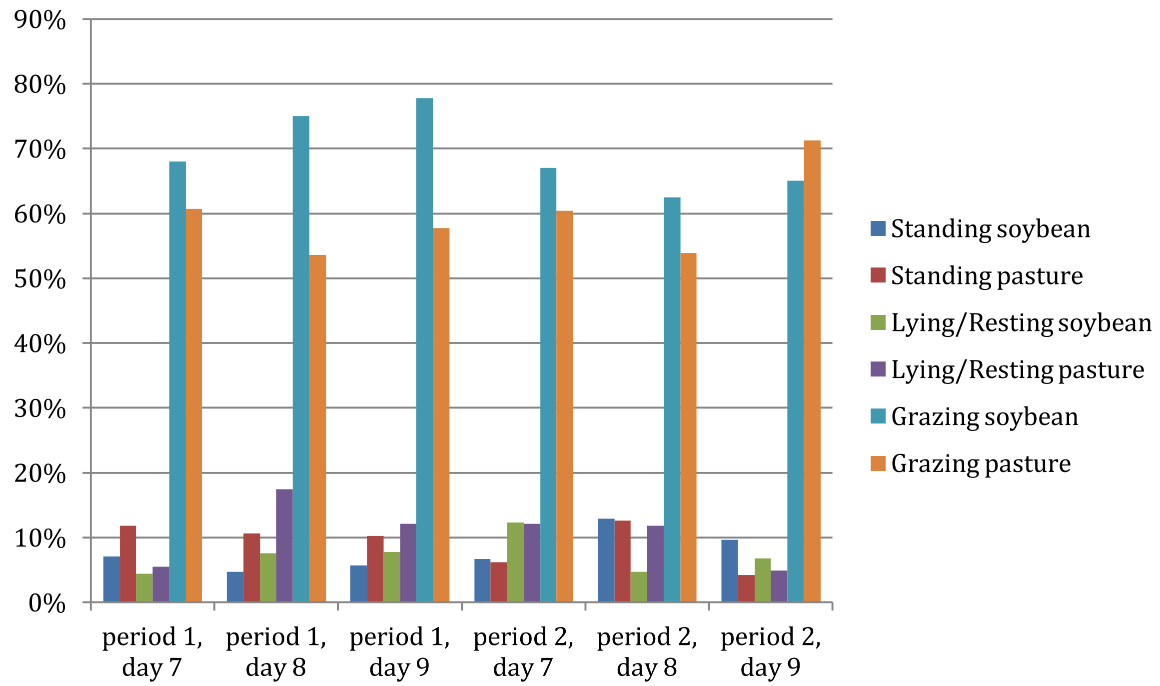


Figure 1: Proportion of observed behaviours, as a percentage of total behaviours observed, between soybean and pasture treatment paddocks

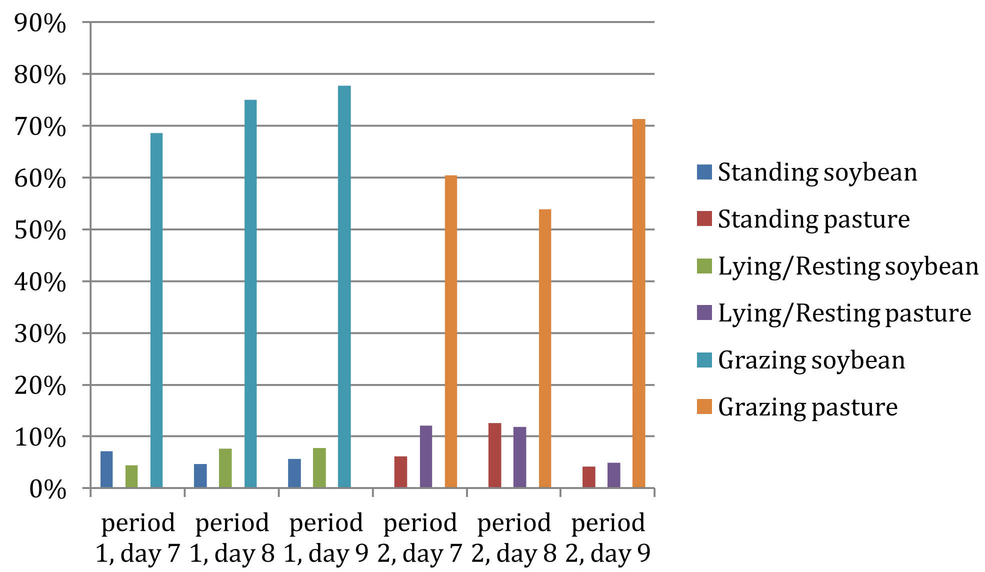


Figure 2: Proportion of observed behaviours, as a percentage of total behaviours observed, between soybean and pasture treatment paddocks for Group A

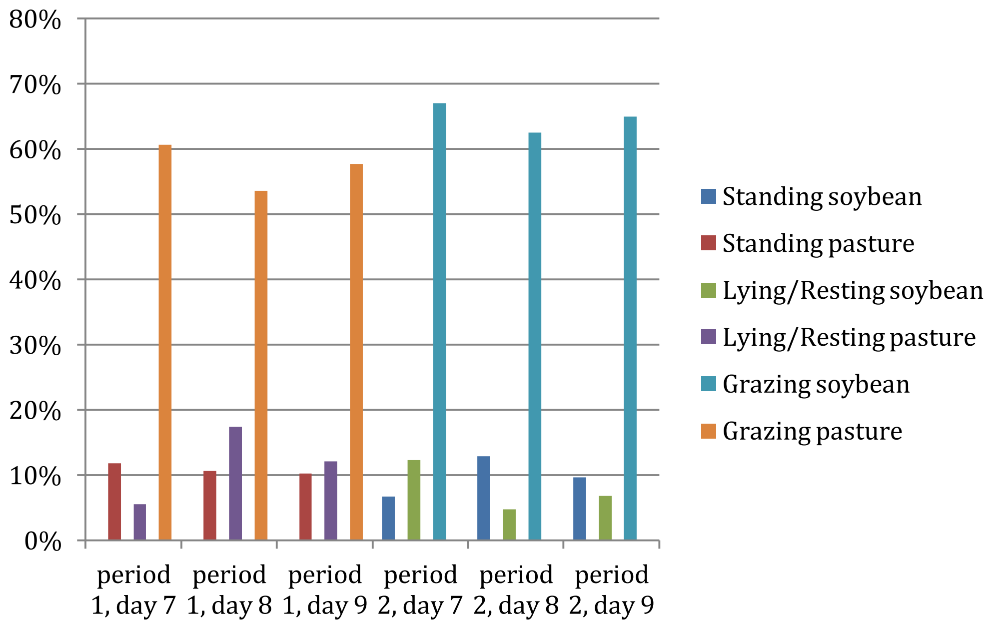


Figure 3: Proportion of observed behaviours, as a percentage of total behaviours observed, between soybean and pasture treatment paddocks for Group B

Regardless of whether it was the morning or afternoon, the most commonly observed behaviour was grazing (Figures 4 and 5). During the morning cows in the pasture spent more time grazing on the fifth and sixth day, compared to soybean. During the second part of the trial it is also seen that cows in the soybean tended to show more resting behaviour than the cows grazing pasture. Cows in both treatment groups grazed more during the morning compared to the whole day.

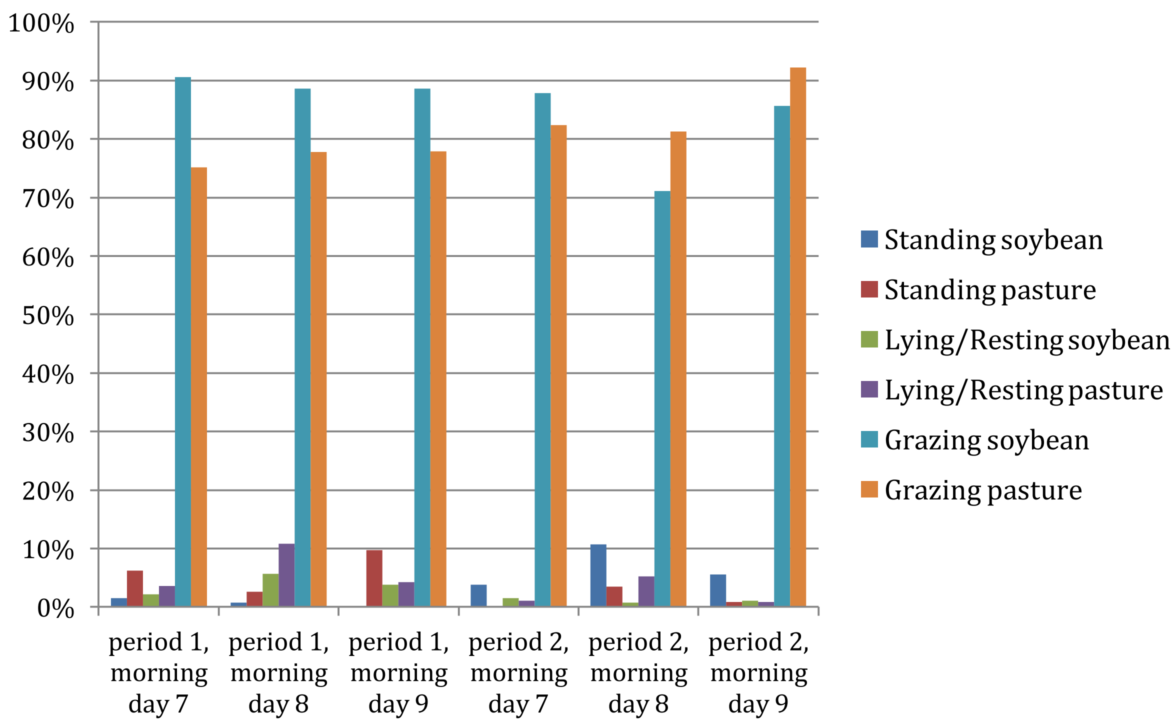


Figure 4: Proportion of observed behaviours, as a percentage of total behaviours observed, between soybean and pasture treatment paddocks during the morning (0900-1300)

The results seen in Figure 5 are similar to Figure 1. The cows spent more time grazing soybean than pasture throughout the study, with the exception of day six, where cows spent more time grazing pasture. In the first period the cows grazing soybean spent less time on resting behaviour, while in the second period there was more resting behaviour in the soybean paddock. Cows tended to spend more time resting (lying and standing) and less time grazing during the afternoon, compared to the morning and during the whole day. In the afternoon a greater proportion of behaviour was recorded as ruminating, however this is not presented here.

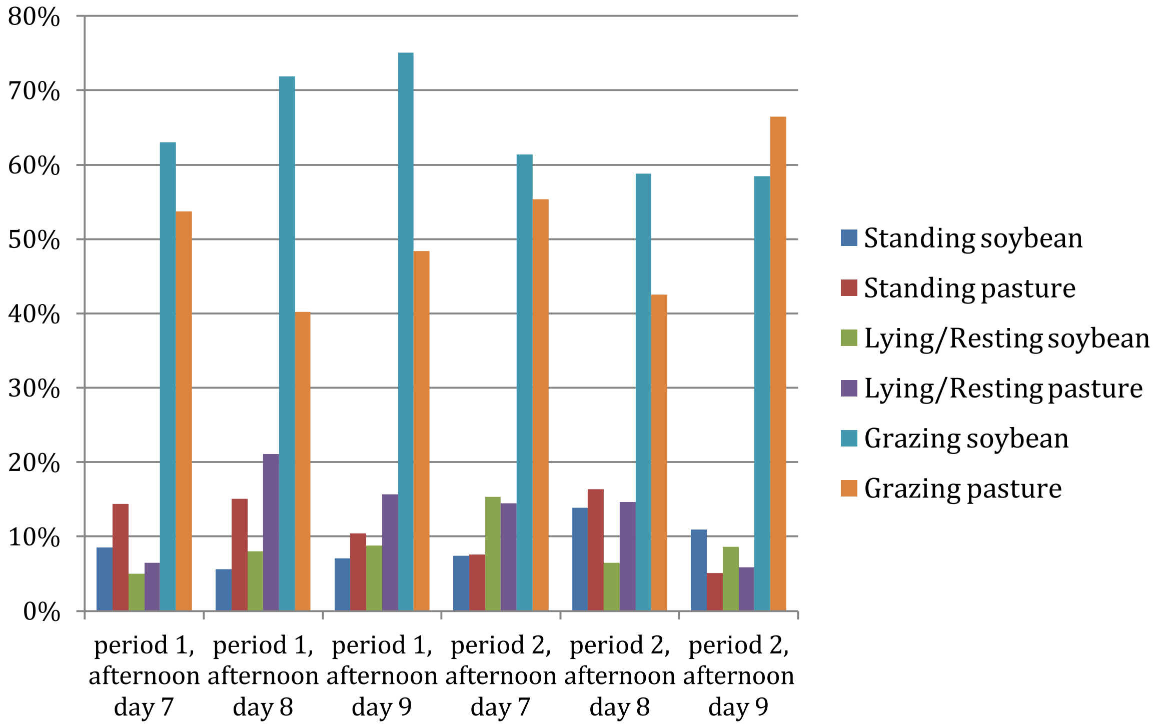


Figure 5: Proportion of observed behaviours, as a percentage of total behaviours observed, between soybean and pasture treatment paddocks during the afternoon (1300-1700)

***Cow traffic***

The best model consisted of day, treatment, Catlactation, CatDIM and yield. This was the model with the lowest AIC. After running the model a Q-Q plot of the residuals was made to study normality. The Q-Q plot was found to be normal; the plot was a straight line and only at both ends some deviation could be seen. Multiple Scatterplots were made to test linear regression. All assumptions underlying linear regression were satisfied; the Scatterplot of the residuals and the predicted values showed a linear relationship (the residuals were randomly scattered around zero), the residuals were normally distributed (the Q-Q plot was normal) and the variability of the residuals was constant throughout the range of predicted values (the residuals were randomly scattered and no funnel or cone effect was visible).

The average waiting time was 1 hour, 51 minutes and 5 seconds for all the cows.

The waiting time was lower for cows with a low CatDIM (CatDIM compared to cows with a higher CatDIM (Table 4). The average waiting time per treatment was 1 hour, 47 minutes and 4 seconds when grazing soybean and 1 hour, 54 minutes and 3 seconds when grazing pasture.

Table 4: average waiting time (hours:minutes:seconds) per CatDIM

| CatDIM | Average waiting time |
|---|---|
| One | 1:50:17 |
| Two | 1:38:51 |
| Three | 1:40:34 |
| Four | 1:58:55 |
| Five | 2:06:47 |

The type III Tests of fixed Effects (summarized in Table 5) showed that there was a significant effect for Catlactation, CatDIM, day and yield on milking interval. There was no significant effect of treatment on milking interval. The same values of significance are seen in the Univariate tests. These tests show the effect of each particular factor on the milking interval.

Table 5: Effect of factors on the dependent interval (milking interval)

| Factor | Significance |
|---|---|
| Treatment | .233 |
| Catlactation | .020 |
| CatDIM | .000 |
| Day | .000 |
| Yield | .000 |

There were also differences within the factors. These are shown in Table 6.

Catlactation two had a significantly shorter milking interval than Catlactation three. Catlactation one was also found to have a shorter milking interval compared to Catlactation three, but this was not significant according to the Pairwise comparisons. The shortest mean estimated milk interval was seen in Catlactation two (14 hours, 48 minutes and 25 seconds) while Catlactation three was found to have the longest (17 hours, 33 minutes and 20 seconds).

CatDIM one, two, and three were significantly lower compared to CatDIM four and five. The shortest estimated mean milk interval (13 hours, 56 minutes and 10 seconds) was reached by the cows that were between 61 and 120 DIM. Cows that were more than 305 DIM had the longest mean estimated interval (18 hours, 57 minutes and 9 seconds).

The shortest estimated mean milking interval (15 hours, 7 minutes and 10 seconds) was seen on the fifth day of the trial, while the longest was on the second day (17 hours and 19 minutes). There was no significant difference between the first day and all the other days of the trial. There was also no significant difference between the last day and the other five days of the trial. There was however a significant difference between the second and the third day, the second and the fourth day and the second and the fifth day.

Table 6: Mean estimated milking interval (hours:minutes:seconds) for each of the different factors in the model

| Treatment | Mean | Std. Error | df | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|
| **Soybean** | 15:44:47[b] | 24.24 | 3:24:34 | 14:56:40 | 16:32:55 |
| **Pasture** | 16:04:46[b] | 24.32 | 3:27:37 | 15:16:23 | 16:53:08 |
| **Lactation 1** | 15:22:36[b] | 38.18 | 2:49:57 | 14:06:58 | 16:38:13 |
| **Lactation 2,3,4** | 14:48:25[b] | 29.01 | 2:56:36 | 13:51:07 | 15:45:43 |
| **Lactation 5,6,7,8,11** | 17:33:20[b] | 50.28 | 2:43:40 | 15:53:40 | 19:13:00 |
| **< 60 DIM** | 14:26:11[b] | 49.50 | 3:11:26 | 12:47:52 | 16:04:29 |
| **61-120 DIM** | 13:56:10[b] | 41.30 | | | |
| **121-200 DIM** | 14:35:31[b] | 41.02 | 4:29:22 | 13:14:43 | 15:56:20 |
| **201-305 DIM** | 17:38:52[b] | 40.10 | 4:02:09 | 16:19:45 | 18:57:00 |
| **>305 DIM** | 18:57:09[b] | 50.08 | 3:28:06 | 17:18:17 | 20:36:02 |
| **2-2-2012** | 16:06:02[b] | 30.37 | 6:33:30 | 15:05:49 | 17:06:15 |
| **3-2-2012** | 17:19:09[b] | 29.07 | 5:52:28 | 16:21:53 | 18:16:25 |
| **4-2-2012** | 15:15:36[b] | 29.22 | 5:54:18 | 14:17:49 | 16:13:23 |
| **9-2-2012** | 15:42:57[b] | 30.26 | 6:25:24 | 14:43:06 | 16:42:47 |
| **10-2-2012** | 15:07:06[b] | 28.30 | 5:33:33 | 14:11:02 | 16:03:10 |
| **11-2-2012** | 15:57:51[b] | 30.48 | 6:40:11 | 14:57:16 | 16:58:25 |

a. Dependent Variable: Interval.
b. Covariates appearing in the model are evaluated at the following values: Yield= 11.45

As mentioned above there was no significant difference on the milking interval between cows grazing soybean and cows grazing grass. However there was a trend that milking interval was slightly shorter when cows grazed soybean (Table 6 and Figure 6).

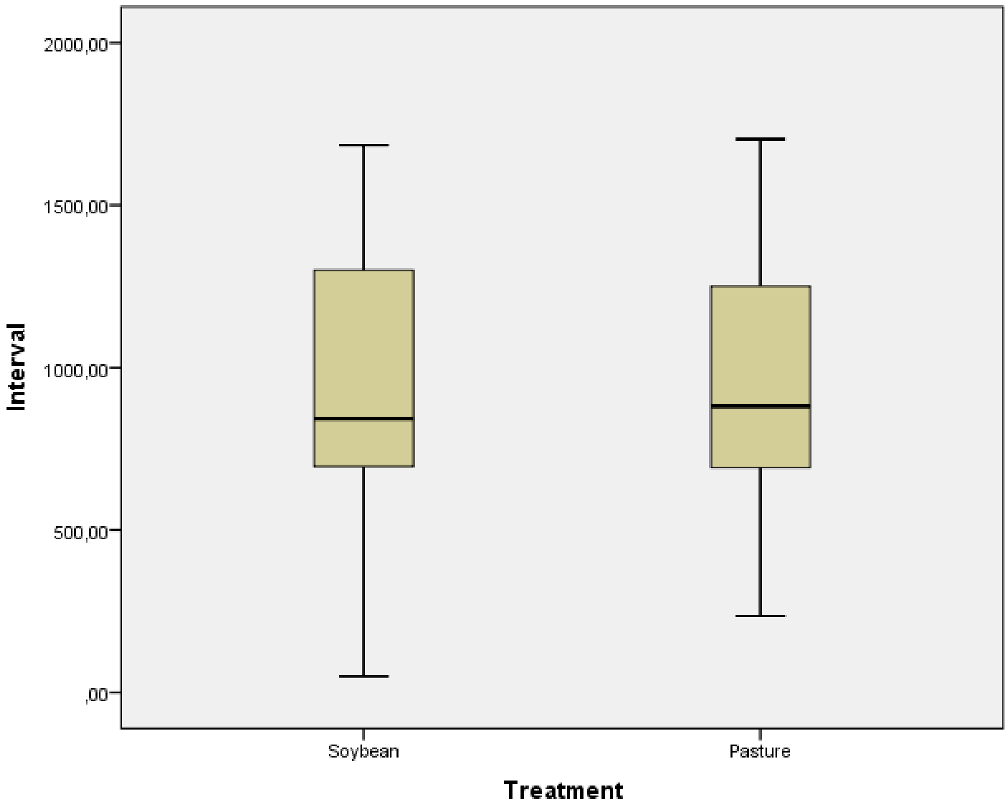


Figure 6: Boxplot comparing the mean milking intervals of soybean and pasture across all observation days

## Discussion

If pasture-based grazing is combined with an AMS, cows are required to voluntarily return to the dairy from pasture with minimal assistance by the farmer. Earlier research showed that food is an effective incentive for encouraging cows to traffic, and importantly to come to the dairy.[8,11,13] Increased cow traffic can lead to increased milk yield, and it is therefore import to investigate the use of incentives to encourage cow traffic in AMS, aiming to shorten the milking interval and increase the milking frequency, and subsequently the milk yield.

It is difficult to quantify the impact of pasture species on voluntary cow movement, because there are many factors influencing cow traffic such as lactation, milk yield and DIM. [9] That DIM influences the milking interval is also current in the current research. Cows with more than 201 DIM had on average a longer waiting time, thus influencing the milking interval. The current research also showed that offering cows soybean plants to graze reduced the milking interval when compared with cows grazing pasture, however this trend was not significant. Previous research has found that soybean is preferred over other species by grazing diary cattle.[4] This can explain why cows spent more time in the soybean paddock and why the daily intake per cow was higher compared to pasture.

At present there is very little known about the effects of incorporating forage crops as incentives for cow traffic in AMS. There is also limited knowledge about grazing behaviour in AMS. Previous research has found that in conventional farm systems (with two milkings) cows had approximately five grazing periods per day. The first grazing period is shortly after sunrise and the longest grazing period is in the evening and lasts until shortly after sunset. In between the milkings cows will have two to three grazing periods.[14,18] In the current study cows were observed to graze less during the afternoon, compared to the morning. It may be possible that cows have longer resting periods in between grazing in AMS, and that grazing behaviour could differ to that in conventional systems because the cows are going to multiple paddocks during the day. Since observations ceased at 1700, it is not known if the cows increased their grazing time around sunset. More research is warranted if we are to fully understand the grazing behavior of cows managed with AMS.

Cows tended to graze less during the afternoon, and this may have been related to pasture quality. It is proven that cows avoid the less tasty and less nutritious plants close to faecal deposits.[13] As the day progresses, more areas of the allocation become 'contaminated' with faecal deposits, along with a greater proportion of the allocation being depleted. This may have contributed to less grazing behaviour being observed in the afternoon in the current research. The lack of a significant effect of soybean on cow traffic and behaviour in the paddock may have been caused by several challenges faced whilst growing, and grazing, the soybean crop. During the growing period, heavy rainfall stumped the growth of the soybean, while a large portion (approximately 30%) of the crop was destroyed by wild ducks. During the study itself, rainfall may have impacted on grazing behaviour. However both treatments were run simultaneously and therefore were both subject to the adverse weather conditions during observations.

Cows spent more time grazing pasture on the sixth day of the trial compared to the soybean paddock. It may be that a reduction in the quality of the soybean (through increased plant maturity) towards the end of the study lead to cows spending less time grazing soybean compared to the pasture.

Cows show synchronized behaviour.[5,9] This might explain why all the cows leave the pasture paddock around the same time during the second day of the trial. At that point the pasture was not depleted and there was still sufficient pasture available for cows to continue grazing. Synchronized behaviour is however not seen on such a scale during the other days of the trial. It is possible that there is another reason why the cows left all at once.

Weather is known to impact on cow behaviour.[5] Throughout the study, cows experienced a variety of weather conditions, including heavy rainfall, storms and the occasional hot/humid day. It may be that the weather influenced cow traffic and behaviour, particularly when cows tend to spend more of their time indoors on hot days. Cows can also move indoors or alter their behaviour during heavy rainfall.[5,8,9] It is possible that fewer cows came to the paddock because of the weather. The grazing behaviour might also be different when the plants are very wet.

During the trial there was one major breakdown of the RR. This happened in the afternoon of the last research day, just before the close of the active access time (1500), so some cows weren't able to go to the paddock at the usual time. Unfortunately the breakdown narrowed the data.

## Conclusion

There was a trend that cows spent more time grazing in the soybean paddock and less in the pasture paddock. This trend was also true when looking at the group (A and B), where regardless of the period cows were allocated to soybean, they were observed to be grazing more often than when they were allocated to pasture. Cows in the soybean paddock consumed twice as much compared to the cows in the pasture. Cows tended to graze more often in the morning compared to the afternoon, during which they tended to exhibit more resting behaviours. Cows also stayed longer in the soybean paddock compared to the pasture. A difference in milking interval between treatments was observed, where the mean milking interval was slightly shorter when cows grazed soybean. However the difference was not statistically significant. Day, Catlactation and CatDIM had a significant effect on the milking interval. Older cows and cows that were later in lactation (longer than 305 days) had on average a longer milking interval, therefore keeping the calving interval low and managing long milking intervals could assist in improving cow traffic around the farm system. Despite soybean not significantly effecting voluntary cow traffic, it may still be able to be incorporated into AMS as complementary forage rather than as an incentive to increase cow traffic. Further research could be focused on the effect of the proximity (to the dairy) of offering soybean or another forage crop as an incentive.

## Future research

Only the milking intervals from the cows leaving the dairy between 0900 and 1500 were compared in the current study, narrowing the data set. In future research it would be good to look at all the milking intervals during the six days of the trial. The difference in milking interval could be different if you take all the intervals into account.

Another reason why it would be better to look at a 24 hour period is the milk yield. Some cows only have one milking per day, while other cows may have multiple milkings per day. Cows visiting the dairy on multiple occasions during the day may have a higher total milk yield compared to cows that visit the dairy only once a day. The milk yield from a single milking depends on the robot performance, cow behaviour at milking (whether she kicked a cup off or not), and how long it was since she last came to the dairy. So for comparing yield it is better to use daily yields instead of the yield of one single milking (which was done in the current research). When using daily milk yield high producers can be identified as well. Using daily yields might have changed the categorization of yield. The average yield per lactation will probably be higher and cows will have another categorization (zero or one).

Since the categorized yield was not in the best model, another categorization should be used in future research. There may be a correlation between DIM and yield. Categorization of yield according to DIM or CatDIM could be a better option.

In the current research a comparison is made between grazing soybean and grazing pasture. Since there is a great difference in individual milking interval it might be better to compare within Group A and Group B.[7] So to compare grazing soybean in Group A to grazing pasture in Group A and the same for Group B. This makes the differences between the groups as small as possible and might have another outcome because it rules out individual cow differences.

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## Appendix

## Behavioural observation instructions

### General –

In each paddock at any point in time, there will be two observers. Each observer will be dedicated to one of two tasks; positioned at the entrance gate to the paddock ("gate"), and positioned alongside the paddock ("paddock"). **ALL** cows in the herd should be observed (ie. all cows in your allocated paddock should be observed).

### Conducting observations –

Cows will be arriving in the paddock from 9 am. When in the process of observing animals, finish the observation prior to changing over observers. The observer being relieved (eg. the observer who commenced at 9 am) should conduct the "on the hour" observation (eg. the 1 pm observation).

The person observing until 1700 makes the final observation at 1700. Once the observations are completed, all the cows remaining in the paddock are pushed out of the paddock, and the gate is closed behind the cows (an electric fence tape, it will have a hook to latch onto the fence). Cows are being pushed along the laneway until a one-way gate is reached (it is a narrow gateway with a swinging gate attached) and the cows pass through it.

**a) Gate**

As an individual cow passes the gateway, the time will be recorded as she passed the gateway. Her identification number and the direction in which she was moving (in or out of the paddock) will also be recorded. Cows will be arriving at the paddock after 0900. Recording sheets will look similar to fig. 6.

Observer: ______________________ Paddock: Soybean No9

Date: ____________________ Time commenced: ____________________

| Cow number | Time | Action | | | Cow number | Time | Action | |
|---|---|---|---|---|---|---|---|---|
| | | In | Out | | | | In | Out |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Figure 6: example of the entering and exiting sheet

A cow is considered to have entered the paddock when both her front legs have passed through the gateway into the paddock. A cow is considered to have left the paddock when both front legs have passed through the gateway into the lane.

A stop watch is to be used for recording the time a cow entered/exited the paddock. This will be correlated with other recording devices.

## b) Paddock

At 15 minute intervals (starting on the hour), all cows in the paddock are observed starting each time at the gateway end of the paddock. A Dictaphone is used to talk into when walking up the paddock. At the start of each 15 minute interval, the starting time is recorded into the Dictaphone, followed by the observations of the cows in the paddock (eg. 0945. Grazing, resting, standing and ruminating, grazing .... etc). Only one behaviour per cow is recorded in any single observation period.

Two seconds are being spent observing each cow, taking a “snap shot” (similar to taking a still photo) and the behaviour you see in the snap shot is dictated into the Dictaphone. It is important that as you progress up the paddock, you do not take your eyes of the cows (this is the reason for the Dictaphone). In this way, the chance of recording the same cow twice or missing a cow is minimized.

After observing the cows the recording is played back to tally the observed number of cows displaying each behaviour (fig. 7). Return to the gate way of the paddock in preparation for the next observation.

Observer: ________________ Paddock: Soybean No9

Date: __________________ Time commenced: ________________

| Time | Total cows | Standing idle | Lying idle/resting | Walking | Grazing | Ruminating | | Other |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Standing | Lying | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Figure 7: example of observation sheet

Within the sheet itself, the criteria belonging to each behaviour can be seen below:

- Time:
  At each 15 minute interval observation the commencing time is recorded.
- Total cows:
- After tallying the observations, the total number of cows observed is counted and written down for every individual observation time.
- Standing idle:

Cow is standing still with all 4 "feet" on the ground. She is not ruminating or grazing, defecating, urinating or grooming. She may show slight head/ear movement.

- Lying idle/resting:
  Cow is lying on the ground, not ruminating or grazing, defecating, urinating or grooming. She may show some head/ear movement, and her head may be resting on herself, the ground or another cow.
- Walking:
  Cow takes several consecutive steps with her head raised.
- Grazing:
  Cow has her head down, biting or chewing plant material. She may raise her head no higher than her body height (no higher than her back line) and must continue chewing. She may take several steps, but her head is lowered.
- Ruminating:
  - Standing
    A cow is standing on all 4 "feet" with her head raised. She must make several consecutive "chewing" movements with her mouth. She may swallow and continue chewing.
  - Lying
    A cow is lying on the ground, making "chewing" movements with her mouth. Her head must be raised (not resting on any object). She may swallow, but must continue chewing.
- Other:
  May include behaviours such as grooming, defecating, urinating, belching, scratching, "fighting" with another cow (may include head butting, nudging – in an obvious way, not as the result of moving past and "brushing" another animal), mounting another animal or being mounted. Any other behaviour not specified in the above list.

Summary

- Each observation interval is started at the gate entry end of the paddock
- Every animal is observed in the paddock at 15 minute intervals
- Each animal is observed during 2 seconds; the behaviour is dictated and keep looking at the paddock while doing this.
- After the observations (ending at the farthest point from the gate entry), the recording is played back and the number of animals showing each behaviour is tallied.
- An animal may only fit into one category at any single observation