A genetic analysis of traits recorded by automatic milking systems - the possibility of a new method to evaluate temperament of dairy cows

Ellen Rinell

Norwegian University of Life Sciences
Department of Animal and Aquacultural Sciences
Master Thesis 30/60 credits 2013

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ABSTRACT

The increasing popularity of automatic milking systems beginning in Northern Europe and spreading to other parts of the world requires a re-evaluation of breeding goals for dairy cattle. Workability traits, including temperament, become more important because cows must make their own way to the milking unit and stand quietly while being milked. Fetching of cows, which increases labour requirement, should be minimalized. Besides the apparent benefits of a decrease in labour and an increase in flexibility for farmers, AMS also can record substantial amounts of data on cows. This data, when handled correctly, has the potential to be used in genetic evaluations to obtain estimates of breeding values and heritability. Records from 1674 Swedish Holstein cows from 17 commercial AMS herds were used to estimate heritabilities and variance components for 2 different teat cup kick-offs traits and milking interval. Because these traits are hypothesised to be related to temperament, genetic correlations with temperament scores were estimated. Heritability for the kick-off traits were 0.06 to 0.31 and milking interval was estimated at 0.17. Heritability for temperament score was estimated at 0.14 using scores on 1833 cows from 15 of the 17 herds. Genetic correlations between AMS data and temperament scores were moderate and significant for the two kick-off traits, r= -0.38 and -0.50 indicating that a higher temperament score (a more calm cow) could indicate less kick-offs. Results suggest that data from AMS could provide an objective method to measure temperament in dairy cows.

INTRODUCTION

Since the early 1990s the number of automatic milking systems (AMS) also known as voluntary milking systems (VMS) in northern Europe has been on the rise. Approximately 25% of Sweden's dairy farms are equipped with AMS, commonly termed milking robots (de Koning et al. 2010). As more farmers make the conversion to milking with robots, a re-evaluation of breeding goals is needed. The introduction of automatic milking brings about a significant alteration in the way cows are milked; no longer are they driven to a parlour by the farmer, but they must make their way to the automatic milking unit (AMU), commonly called the milking box, on their own accord. This requires emphasis on traits that have had a different optimum in conventional parlour systems, such as temperament.

Temperament is commonly defined as the animal's fear response to humans. Temperament is a functional trait that is usually categorised under "workability". Workability is probably best described as the animal's suitability to carry out a purpose on the farm. Along with temperament, it can include ease of handling and milkability. Under the category of milkability, traits like milking speed and average flow rate are evaluated. König et al. (2006) recommended further studies of behavioural traits using AMS data in order to further develop breeding strategies and determine what defines good temperament for cows in an AMS.

The purpose of this project is to find out if data recorded by AMS can be used in genetic evaluation by estimating heritabilities of teat cup kick-offs and milking interval and their genetic correlations with temperament, a trait already in the breeding scheme in Sweden and many other countries. The hypothesis is that the traits milking interval and teat cup kick-offs, recorded by automatic milking systems, are heritable and can be included in the breeding goal since they are correlated with temperament. If this is true, perhaps a more objective, accurate and automatically recorded assessment of temperament could be developed. In this report, research completed in the areas of animal behaviour and animal breeding to accommodate new milking systems will be outlined in order to provide a basis for the analyses we carried out. Then our research process will be described and we will draw conclusions both from what our research showed us as well as how it relates to the literature and what we recommend for selection of cows for milking robots.

LITERATURE REVIEW

Starting with the first usage of AMS in the early 1990s and continuing with the steady incline in the early 2000s, many studies have focused solely on cows kept on farms with one or more AMS. A substantial amount of studies have looked into what is different in regards to cow health, ie. lameness and mastitis incidence, milk quality and animal welfare. A significant amount of studies have also tried to find the best system for cow traffic and barn layout in an AMS. While these studies are important, this literature review will focus on preferred cow behaviour in an AMS, cow welfare and the genetic basis of dairy cow behaviour in order to gain a better understanding of what has been found to be necessary or desirable characteristics of cattle that are robotically milked.

Background information on AMS

The development of automatic milking systems began with equipment that could automatically attach teat cups. In 1992, the first commercial milking robots came into use. Since 2008, AMS have substantially increased in popularity, and as of 2008 there were more than 8000 farms in 25 different countries using AMS. The regions with the greatest adoption of milking robots are Scandinavia with a quarter of farms having an AMS and the Netherlands, which has 2000 farms with robots. A single stall robot system can milk 55-65 cows per day, so this may be one of the reasons why adaptation is most prevalent in northern Europe as the farms are a suitable size (de Koning et al. 2010).

Reasons for converting to AMS

An increase of desire for a social life and more freedom has led many farms to take advantage of new technology. Two-thirds of farmers say that a better social life is their reason for investing in an AMS (Mathijs et al. 2004). With an AMS, the farmer does not have to be present at what would be the routine milking times in a parlour system or have to pay and rely on employees which have a high turnover rate in some countries. This is the most common reason for the conversion to automatic milking. In addition to lower labour requirements, AMS results in a 5-10% increase in milk yield which is mainly due to the increased milking frequency (de Koning et al. 2010). Although the benefits reaped from an AMS are extensive, there are a few drawbacks. Milk quality can be reduced in some cases, welfare and health can be compromised due to more sporadic observation of cows and it is more difficult to implement into a pasture-based system and can cause issues with cow traffic in the barn (de Koning et al. 2010).

Economic considerations regarding AMS

Whether it is a value of an increased opportunity for a social life, the increase in milk yield or both, economic concerns are the basis for investment in an AMS. Economic benefits from converting to AMS vary from country to country based on the cost of labour and farm size. One of the most appealing aspects of converting to AMS is that a 20-30% reduction in labour can be expected in most cases. However, the areas of attention are shifted from the milking parlour to visually observing cows and retrieving cows that exceed the desired milking interval. AMS need a person on-call at all times because system failures are frequent, occurring on average once every two weeks (de Koning et al. 2010).

5-10% of farmers switch back to conventional milking after converting to an AMS (de Koning and Rodenburg et al. 2004). This is mainly due to unrealistic expectations of how machines should function and a high failure rate can be discouraging. Therefore, successful adaption to an AMS system requires skilled support, flexibility, technological adeptness, and smooth functioning of cow traffic. Furthermore it requires farmers to be flexible and open to change and cows to be in good health – especially in their legs and hooves - and have healthy appetites (Mathijs et al. 2004).

Data recording

Another benefit of AMS is that they have the ability to record cow parameters at every milking. Sensors not only register the cow's ID and record milk yield, but can also measure things such as milk flow rate (from all four teats separately), somatic cell count, and the amount of times the cow kicks off the teat cups. It records milking interval so it is ensured that an appropriate time has passed since the previous milking and can notify the farmer if a cow has gone too long without milking and needs to be fetched. These data, which must be handled wisely and with appropriate software because it can seem like there is an excess, can be used to make conclusions about the herd for breeding and health and can lead to better management practices. One of the most important benefits of the AMS is that cow parameters are automatically recorded which does not require any extra work from the farmer or veterinarian to evaluate many aspects of the herd.

Cow behaviour in and around AMS

Cows' motivation to visit AMS

A significant difference which must be considered when using an AMS verses a conventional parlour, in terms of demands on cow behaviour, is that cows must determine when they will get milked. The first stage is acclimation to an AMS, which only takes a few days in most circumstances (Winter and Hillerton 1995). However, adapting to a new system may be more difficult for some cows than others (Wenzel et al. 2003). Cows are quick learners and easily adjust to changes in their environment (Albright et al. 1981). In most AMS cows have two motivations to enter the robot: access to concentrate and emptying of the udder. In a standard AMS, concentrate is provided in predetermined quantities to the cow while she is being milked. In controlled-traffic systems, cows achieve access to the feeding area after being milked. Therefore, this system depends on cows' motivation to eat at regular intervals (Winter et al. 1995). With free access, cows do not have to be milked in order to enter the feeding area. They will eat 7-10 times per day with this system (Pirkelmann et al. 1992).

Typically, cows eat 5.9 times per 18 hour day. A study done by Winter et al. (1995) considered 18 hours a day because the majority of milking and feeding occurred between 06:00–00:00, which comprises approximately 29% of the day and 303-333 minutes per cow. The mean milking visit in this study was 10.97 minutes and milking duration was 4.8 minutes, and the first milking of the day was the longest (Winter et al. 1995). Since being milked is a significant part of a cow's day, considerations of cows' habits of the time of day they prefer to be milked must be evaluated since all cows must have a chance to visit the AMS. In another study, robot visits peaked at 05:00 and between 12:00-16:00 and then again from 20:00 to 23:00 (Stefanowska et al. 2000). If these are the preferred intervals for milking, the question of which cows will be successful in being milked at these times is brought up.

Social Behaviour

Cows are naturally gregarious and up to 70 animals in a herd have the ability to recognize each other (Broucek et al 2004). Because of strong social bonds and hierarchy structure, it may be problematic for them to come to the milking robot at regular intervals. Therefore, more individualistic behaviour, or the willingness for the cow to separate itself from the herd, is preferable for use of the AMS. A study by Winter et al. (1995) was done to see if cows can integrate AMS into normal diurnal patterns of behaviour. The cows showed synchronized behaviour only 0.44% of the time. Synchrony of feeding was only by chance. Cows milked in AMS had less synchrony of behaviour.

Appropriate social behaviour is especially important in an AMS because competition at the entrance occurs. In a study by Lauwere et al. (1996), cows with a higher dominance value spent less time in the waiting area. It has been reported that a higher dominance value corresponds to a greater milking frequency, with a phenotypic correlation of 45%. This study showed that high- and mid- ranking cows adjust their visiting behaviour based on how much concentrate is provided. However, low-ranking cows did not change their routine when provided with less concentrate (Lauwere et al. 1996).

Fetching cows to bring to AMS and ensuing problems

Fetching cows, or in other words, going to retrieve them when the AMS registers that they have not been milked in a set amount of hours, costs the time of the farmer or the labour of employees. In two studies by Stefanowska et al. (2009), the first in which the AMS was available from 05:00 until 23:00 and the other in which the AMS was available at all hours, cows had to be fetched for milking in 8% of all visits. Fetching is a new concern when introducing AMS and is something that compromises both profit and cow welfare, so it is important that the need for fetching is minimalized.

What affects the milking frequency and in turn, the prevalence of fetching? Besides the farmer's ability to set the preferred interval between milkings on the AMS, it is the cow's motivation to be milked. This is, for the most part, either influenced by a full udder or being provided with concentrate in the milking robot, or both. What is of concern regarding temperament is when cows have the obvious motivations to visit the robot but are not doing so, especially those who are at peak lactation (Nixon et al. 2009). This could indicate that something else is hindering them from entering the AMU.

Avoidance of the AMU can also be related to a fear of humans and therefore an unfavourable temperament. One study found that fetched cows show a greater avoidance of human approach (Rousing et al. 2006). However, there were no significant relationships between stepping and kicking at milking and fetching. Since cows can experience fear from being fetched, fetching can also present a welfare issue. In a study by Hopster et al. (2002), cows experienced higher levels of adrenalin and noradrenalin plasma concentration which resulted from being fetched.

Kicking and behaviour problems in milking machine

Kicking of the cow while inside the AMU can present many problems. First of all, it can cause wear and tear on the robot, and a higher chance that the robot will stop functioning normally. Kicking can cause damage to both the teat cleaning devices and the teat cups. It can result in incomplete milking and consequently less milk yield, as well as longer attachment time (Rousing et al. 2004).

Cows kick off the teat cups for a multitude of reasons. The teats could be sore from mastitis and/or of being milked too frequently. Otherwise, the cow could have an undesirable temperament. In one study, 13% of cows kicked at least once during the milking process, and 4% more than once (Rousing et al 2006). The high incidence could suggest that many cows are uncomfortable or possibly even nervous while in the AMU.

A study by Kaihilahti et al. (2006) found that failures during milking were caused by cows 55% of the time and by the machine 45% of the time. In this study, which involved the use of video cameras, showed that 28% of the cows started kicking the robot arm just as the washing process started, and 19% kicked off the teat cups during milking. This represented 50% and 34.5%, respectively, of the failures caused by cows using the AMS (Kaihilahti et al. 2006). This behaviour caused subsequent problems to increase during the whole milking process, and these cows were likely to be culled. Moving or kicking in the AMU can also present difficulty for the robot to find the teats.

Not just kicking, but stepping, or “shuffling” in the AMU could also indicate that cows are uneasy while in the milking robot. In a study by Wenzel et al 2003, it was shown that cows using milking robots stepped more in the milking robot than in a conventional parlour. However, there was no significant difference found in the amount of kicking (Wenzel et al 2003). Although kicking, stepping and having to be fetched all represent behavioural issues in cows, it has been shown that there are no significant interactions between kicking and stepping during milking and fetching (Rousing et al 2006).

Effects of barn layout and traffic system on cow behaviour

The layout of the barn and type of traffic system can directly affect cow behaviour. There are two main types of traffic systems in barns with AMS, controlled traffic systems and free cow traffic systems. Controlled traffic systems allow cows to enter the feeding area only after they have been milked by using a one-way gate. On the contrary, free cow traffic systems allow unlimited access to forage. According to animal welfare standards, free cow traffic is preferred because cows should not be denied access to feed according to the Five Freedoms (de Koning et al. 2010).

Robotic milking can present problems when grazing is required, as it is shown that cows are hesitant to visit the AMS when the distance is over 500 meters. Some farms have a system where only the cows that have been milked can go out; others have a system with a mobile AMS. This unit can be driven out to pasture and can operate on its own for two days. It was tested in 2008 and had satisfactory production levels of approximately 7500 kilograms per year (Oudshoorn et al. 2008). The Greenfield Project in New Zealand has shown that 100% grazing is possible with an AMS (Jago et al. 2004).

Welfare considerations in an AMS

Increasingly, consumers request that cows should be on pasture as much as possible to promote better welfare. However, it is more difficult to encourage cows to come in the barn to visit the AMS and walking back and forth also results in extra energy expenditures. If cows are on pasture for most of the day, it is even more imperative that they are both willing to visit the AMS and be cooperative once inside it.

Limited grazing opportunities resulting from being inside of a barn to use an AMS can lead to reduced welfare. However, cows kept in a barn and close to the AMS can be problematic for legislations which require cows to be on pasture a certain amount of weeks out of the year. On a pasture, synchronization of behaviour is pronounced, and a man-made environment can result in loss of synchronization (Winter et al. 1995).

Cows are diurnal feeders, active in the day and rest at night. But mostly they are crepuscular, active at the times of greatest change in daylight – dawn and dusk (Scott et al. 1962). Automatic milking forces cows to be more active at different times of the day, because the entire herd cannot be milked during their preferred active periods. Automatic milking reduces milking time from 20% (in a conventional herringbone parlour) to 3% of an 18 hour day for a single cow (Winter et al. 1993). This could increase welfare by allowing more time for ruminating, lying, sleeping, and social behaviour.

Some experts believe that AMS allow cows to have more control over the milking environment, ie. decide when milking, sleeping and eating takes place. This fits with the theory that the farm should be designed to fit the animal, and not the other way around (Kilgour et al. 1978). However, restricted access to feed as in a controlled traffic system could represent a reduction in welfare, according to one of the five freedoms, freedom from hunger and thirst. Additionally, the ability to express normal inherent behaviour patterns is one of the Five Freedoms, and a system where cows have to wait and compete for access to the robot and in turn, the feed could disturb this pattern (Fraser and Broom 1990). The issue which is brought up by this is if individualistic behaviour, rather than synchronized behaviour, is beneficial or detrimental to welfare.

Rousing et al (2006) attempted to see if fetching of cows for milking had an effect on welfare. In the first 14 days after parturition, the prevalence of fetching was significantly higher than during the remainder of lactation in all eight herds. The study looked at how stepping and kicking and avoidance of a stockperson related to cows' reluctance to enter the milking robot. When cows do not visit the milking robot themselves, farmers must fetch them. This is often due to lameness but also to an aversion to the milking robot for other reasons, like discomfort or fear of the milking box.

Fetching by humans could present welfare problems; it has been shown that adrenaline and noradrenaline levels increase immediatley prior to milking (Rousing et al. 2006). This increase is also evident in cows milked by humans in conventional parlours (Rousing et al. 2006). Fetched cows tended to have lower scores on the human approach test (Hopster et al 2002). Koning and Rodenburg (2004) conclude that some cows are just not meant for AMS. This leads to the suggestion that cows must be selectively bred for functionality with automatic milking.

Characteristics of importance for cows using an AMS

The importance of temperament in AMS

Usage of an AMS requires cows to be more self-motivated and independent in contrast to cows being milked in a conventional parlour. Therefore, their temperament is one of the most substantial concerns in the increasing popularity of the AMS. Temperament has been defined many ways besides the amount of fear an animal shows towards humans. Kilgour et al. (1975) defines temperament as "a set of behavioural characteristics that contribute to the unique disposition of one animal in contrast to other species members." Another has identified the key parts of temperament as being "docility, workability, disposition and fearfulness" (Gutierrez-Gil et al. 2008). In totality, temperament affects the cows' ability to live amiably in a group setting and in contact with humans because it influences how social behaviour and motivation for feed are expressed and levels of assertiveness and aggression.

Quantifying Temperament

Temperament is difficult to quantify objectively and therefore many different methods of measurement are used. Currently, dairy cows in Sweden are evaluated for their general temperament on a scale of 1 through 9, 1 being very nervous (unfavourable) and 9 being very calm (favourable). The farmer rates them and reports to Svensk Mjölk (now Växa Sverige). Only primiparous cows are included in the evaluation. An animal model is used and progeny groups must be at least 15, but the average is 40-50 daughters (personal communication, Jan-Åke Eriksson, Växa Sverige).

Other traits of relevance

In addition to temperament, other traits become necessary to consider in breeding programs with increased adaptation to AMS. These include strong legs and hooves for walking to the robot and teat placement. A good conformation and hoof health is especially important in pasture-based systems in which the cows will walk farther to get to the robot, but this should also be taken into consideration in barns with milking parlours.

Requirements for conformation change slightly when cows are milked in an AMS opposed to a herringbone or rotary milking parlour. Udder conformation, namely, the placement of teats is vital since it is no longer humans who will be attaching the teat cups. Because they are placed on automatically by the robot, appropriate placement of teats on the udder is vital. Also, because cows in an AMS will be doing considerably more walking back and forth to the AMU, structural traits such as strong feet and legs are important.

Milking speed is also important, due to the time constraints of the milking robot. To reach or even increase cow capacity of the AMS, milking speed must improve, especially if the cows are expected to make three visits to the robot per day. Temperament has been found to be correlated with milking speed. Genetic correlation estimates range from 0.41 to 0.53 meaning that a calmer temperament is associated with a faster milking speed (Thompson et al. 1981, Foster et al. 1988, Vischer and Goddard 1995).

Genetic basis of behavioural traits

Introduction of the milking robot requires a re-examination of which traits are desirable in dairy cows and a revaluation of selection methods that best suit cows who must possess different qualities compared to their parlour-milked counterparts.

Over the years there have been several estimates for the heritability of temperament, ranging from 0.06 (Thompson et al. 1981) to 0.53 (Dickson et al. 1970) (table 1). However, problems arise with trying to estimate it. Measurements take place over an extended period of time and some estimates are only based on a few animals (Broucek et al. 2008). Although the same genes are responsible for temperament in both sexes, female animals have been observed to be more difficult to handle and more nervous (Broucek et al. 2008). For some traits, heifers have higher genetic and phenotypic variability than older cows (Gauly et al. 2001). Improving temperament is important from an economic standpoint because not only are animals safer to handle but they also can have a higher average daily gain (Voisinet et al. 1997). It has also been shown that cows with a more aggressive temperament are more reactive (Maffei et al. 2006).

Table 1: Estimations of heritability (h^2) of behaviour in dairy cows, adapted from König et al 2006, Schutz and Pajor 2001, Broucek et al 2008

Study	Trait definition	No. of cows	Method	h^2
Dickson et al. 1970	Temperament	1,107	Paternal half-sib correlation	0.53
Thompson et al. 1981	Disposition	8,977	REML, sire model	0.06
Foster et al. 1988	Disposition	43,428	REML, sire model	0.08
Sullivan and Burnside 1988	Milking behaviour	18,178	Sire model	0.16
Lawstuen et al. 1988	Temperament	9,546	REML, sire model	0.12
Erf et al. 1992	Trouble-free workability	5,353	REML, threshold model	0.11
Visscher and Goddard 1994	Temperament score	14,596	REML, sire model	0.22
Sewalem et al. 2002	Milking temperament	656,839	Animal model	0.08

Most estimates of temperament are based on the experience of the farmer or herdsman. There have not been many studies on traits which could be indicators of good or bad temperament. However, milking interval could be associated with temperament because more visits to the milking unit indicate driven, willing cows that do not need to be fetched. There are other benefits of a decreased interval and therefore a higher milking frequency. Nixon et al. (2009) found that increasing milking frequency from two to three times per day, as commonly done in an AMS increases milk yield from 6-25% per lactation. The same study showed that that it could be possible to select for a shorter milking interval as the heritability of milking frequency is 0.18. In addition, in this study cows that were milked more often appeared to have a lower somatic cell score (r_g= 0.36) although this was not backed up by previous studies. Cows that make more frequent visits to the AMS are more motivated to eat, have less anxiety over the machine and are socially assertive so breeding for more frequent milkings could result in cows with better temperaments (Nixon 2009).

QTL detected for behaviour traits

Since heritability for temperament has been estimated to be low to moderate, there may be a need for information from molecular models to increase the efficiency of selection. Although some quantitative trait loci (QTL) for behaviour in mice have been identified there is not so much information on molecular markers for genes that influence behaviour in cattle (Gutierrez-Gil et al.2008). In a study by Gutierrez-Gil et al. (2008), genome scan of an experimental population of Holstein Charolais F2 crosses was performed. These animals were put through some tests at 10-12 months of age, such as the flight from feeder (FF) test which measured reactivity of animals when they were approached by humans in the feeder and the social separation (SS) test, which measured the responses of animals when separated from their pen mates. A QTL analysis of 12 traits across the 29 bovine autosomes was performed and additive and dominance QTL effects were assessed. Chromosome wide significance levels and genome-wide P-values were calculated. 29 QTL were detected which were spread across 17 chromosomes. Five of these QTL were associated with FF traits and 24 with SS traits and did not overlap. This study only included 137 animals and one significant association was at the genome-wide level. The markers could be used in marker-assisted selection, but solid marker-trait associations must be confirmed (Gutierrez-Gil et al. 2008).

Since human avoidance and separation from pen mates do not appear to be controlled by the same gene, fear may be able to be considered a trait on its own. Fear reactions to humans have been looked into in cattle. Schmutz et al. 2001 detected seven QTL in calves for reactions to humans. Chromosomes 1, 5, 9 and 11 each had one QTL for calves' reactions to humans. With a backcross design, genetic markers were found linking physiological and behavioural reactions to humans in Limousin-Jersey crossbred cattle. Additionally, five QTL were identified for flight distance and three for cortisol (Fisher et al. 2001). As some of these studies are only on beef cattle, more studies are needed on dairy cattle to determine if selection efficiency can be improved by using marker-assisted selection.

Current genetic evaluation of behavioural traits in dairy cattle

On AMS farms, cows are usually culled several days after partuition if they must be fetched too often or are behaving poorly in the milking robot. These cows could do fine in a conventional parlour, but do not function well in the robot. Although this is an effective way for eliminating cows with an unfavourable temperament, there remains a need to develop a more systematic selection process.

In Sweden, farmers report their cows' temperament on a scale from 1 to 9. This is a very subjective scoring method. Also, even if a cow is generally calm she could still kick off teat cups while in the milking robot, so this is not necessarily a valid measurement of the cow's amenability with the machine. The heritability of temperament for SLB (Swedish Holstein) is estimated to be 0.15 using the temperament scoring system 1-9. The permanent environment effect is 0.05 (Swedish Dairy Association). Heritabilities estimated for Swedish Red (SRB) and Swedish Polled Cattle (SKB) are both 0.15. Temperament has a weight of 0.03 in the total merit index for all breeds (NAV 2013). Temperament does have an economic index in NTM. For a farm of 70 cows, if temperament of all cows is one point lower, 5 minutes of extra labour would be required per day (Pedersen et al. 2008). Each additional unit, in theory, results in a gain of 8.50 euros (NAV 2013).

In other countries, temperament is evaluated similarly. Besides Sweden, countries that use a scale of 1-9 are Finland, Denmark, Great Britain, the Netherlands, and New Zealand. Canada, Germany and Austria use a scale of 1-5, and Australia uses a scale of A-E. Switzerland assesses temperament by three different categories: nervous, normal and quiet (Jakobsen et al. 2008). Norway also has a scale from 1 to 3: calm, normal and uneasy/nervous (Geno 2009). Japan has only a two-point scale. Heritabilities in the different countries range from as low as 0.07 (Germany and Austria) to 0.21

(New Zealand) (Jakobsen et al. 2008). Genetic correlations between countries' temperament scores are all above 0.5 and on average is 0.68 (Jakobsen et. al. 2008).

MATERIALS AND METHODS

Description of data

The data from individual milkings, which were provided by Caroline Carlström (Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics), came from 17 commercial AMS herds in Sweden from 2004-2009. Before edits, the data included 1,048,010 milkings of 1,704 first-lactation cows that were milked by DeLaval robots. Observations were automatically recorded in the robots at each milking. The data recorded in the robots included mostly milkability traits, that is, milk flow rate, milk yield, milking interval, visit length, milking time, and the frequency of a cow kicking off the teat cups. In this paper, the number of times a cow kicked off the teat cups and the milking interval will be assessed.

Records of temperament scores came from the Swedish Dairy Association, Svensk Mjölk (Växa Sverige) and included observations on 1833 cows from 15 (of the 17) herds. All of these cows were used in the data analysis. The temperament data was merged with the milkability data, and 597 cows from the robot data also had observations for temperament. Theoretically this would make it possible estimate genetic correlations between the temperament and robot data with a reasonable degree of certainty.

The traits evaluated in this project include kick-offs per milking (NKO), proportion of milkings with one or more kick-offs (PrKO), milking interval (MI) (measured in hours), and temperament score (TS). SAS statistical software (SAS 2010) was used for data edits and analysis.

Table 2. Descriptive statistics of observed values for traits analysed

Trait	**Minimum**	**Maximum**	**Mean**	**N**	**SD**
NKO	0	6	1.18	921,904	2.17
MI	5	29.98	9.72	921,904	2.92
pKO	0	1	0.30	1674	0.22
TS	1	9	5.33	1833	1.26

Edits completed

Several edits were performed on the data using SAS statistical software (SAS 2010) to remove records that were most likely errors made by the AMS. The first through fourth milkings of each cows' lactation were removed to allow for a normal adjustment period as it is found that most cows take about two days to get accustomed to using the AMS. Additionally, any milkings taking place after 400 days in milk were removed. Milkings with intervals preceding them between five and 30 hours and visit lengths of one to 20 minutes were kept in coordination with a similar study done by Carlström et al. (2013). Accordingly, milking times less than 1 minute and greater than 20 minutes were also taken out because it is not feasible that milking time would exceed visit length.

Upon completion of the edits, 12% of the milking events and 1.76% of the cows were lost, leaving 921,904 milkings and 1674 cows for analysis. See figure 3 for the distribution of records over the duration of lactation and table 2 for summary statistics.

Trait Definitions

More than six kick-offs in one milking could be due to an error in the machine. Therefore, we decided to assign any amount of kick-offs 6 or above a value of 6, which created seven different possibilities for a kick-off score.

Two different trait definitions were made to assess the genetic background of the amount of kick-offs. The first, which will be referred to as kick-offs per milking (NKO) was scored from 0-6. All scores represent how many teat cups the cow kicked off during one milking session, except for a value of six. This represents that either six or more teat cups were kicked off during the milking. The second, which will be referred to as proportion of kick-offs (PrKO) was the amount of milking events in which a cow kicked off a teat cup out of the total number of milkings. This trait consists of one observation for each cow during the first lactation whereas the kick-offs per milking has one observation for each milking. Proportion of kick-offs could also be viewed as a probability, i.e. the risk that the cow kicks off one or more teat cup at each milking.

Temperament was recorded on a scale of 1 through 9, 1 being nervous and 9 being calm.

Genetic model

Univariate animal models were used to estimate heritability and repeatability of milking interval, temperament and the two kick-off traits. Bivariate models were used to estimate correlations between the kick-off traits and temperament as well as between the kick-off traits and milking interval, and finally between milking interval and temperament score.

Both milking interval (MI) and number of kick-offs per milking (NKO) were analysed using:

$$Y = \mu + HYS + LW + b\,MY + a + pe + e \qquad [1]$$

The proportion of kick-offs (PrKO) followed this model:

$$Y = \mu + HYS + a + e \qquad [2]$$

The temperament score trait followed the model.

$$Y = \mu + HYS + LW + a + e \qquad [3]$$

where

Y is the individual's phenotypic value for the trait,

μ is the fixed overall mean value for the trait,

HYS is the fixed effect of herd-year-season of the milking in [1], of calving in [2], and of temperament scoring in [3],

LW is the fixed effect of lactation week,

b is the fixed regression coefficient of the trait on milk yield (MY),

a is the random additive genetic effect of the cow, ~ND($\mathbf{0}, \mathbf{A}\boldsymbol{\sigma}_{\boldsymbol{a}}^{\mathbf{2}}$),

where **A** is the additive relationship matrix, going at least 3 generations back, and $\boldsymbol{\sigma}_{\boldsymbol{a}}^{\mathbf{2}}$ is the additive genetic variance,

pe is random permanent environmental effect of the cow, ~IND(0, $\boldsymbol{\sigma}_{\boldsymbol{pe}}^{\mathbf{2}}$), where $\boldsymbol{\sigma}_{\boldsymbol{pe}}^{\mathbf{2}}$ is the permanent environmental variance, and

e is the random residual belonging to the observation, ~IND(0, $\boldsymbol{\sigma}_{\boldsymbol{e}}^{\mathbf{2}}$), where $\boldsymbol{\sigma}_{\boldsymbol{e}}^{\mathbf{2}}$ is the residual variance.

SAS Proc Mixed (SAS, 2002-2010) was used to determine which fixed effects had a significant effect and thus which ones should be included in the model. For the kick-offs (0-6) trait, milk yield and lactation month were the fixed effects. The herd, year, and season of each milking was also included as a fixed effect. For proportion of kick-offs, there was not a significant effect of average milk yield so the only fixed effect was herd year season. For temperament score, HYS and lactation week were both significant effects, but milk yield was not.

DMU (Madsen and Jensen 2006) a genetics software package, was used to estimate heritabilities and genetic and residual correlations.

Correlations

Correlations between temperament score and kick-offs (0-6), kick-offs (proportion) and milking interval were estimated in DMU using bivariate analyses with the same fixed effects for each trait as in the univariate analyses.

Pedigree File

The pedigree file included information on the 1659 animals from the milkability dataset (15 missing) and 1833 animals from the temperament score dataset and their pedigree traced back three generations. There were a total of 10,371 animals in the pedigree file. In the milkability dataset, each sire had on average 4.52 daughters. In the temperament dataset, each sire had on average 3.90 daughters. There were 596 cows in the pedigree which were in both datasets, and each sire had on average 3 daughters.

RESULTS

Significance of Fixed and Random Effects

For NKO, PrKO, and MI, stage of lactation including lactation week, month and days in milk (the quadratic regression) were all found to be significant ($p<0.0001$). When looking at the effects of lactation week it was clear that a simple regression would not be sufficient to describe the dynamics over the lactation. There is definitely a peak in kick-offs at the beginning of the lactation so it is easily seen that lactation stage has an effect (Figure 1). Lactation week was chosen because it is more detailed than lactation month, and easier to visually represent than days in milk. Figures 1 and 2 respectively show the effect of lactation week on kicked off and milking interval. A linear regression on milk yield was significant for both MI and NKO. The herd-year-season of each milking (or of calving for PrKO and scoring for TP) was significant for all traits ($p<0.0001$).

For the temperament trait, HYS at time of scoring and lactation week were significant fixed effects. For PrKO, HYS at the calving date was used as a fixed effect. Including the average milk yield over the entire lactation was considered but there was no significant effect.

Estimates of Heritability

Heritability for the four traits analysed varied from 0.06 to 0.31 (Table 3). Heritability for PrKO was considerably higher (h^2= 0.31) than for NKO (h^2= 0.06). Milking interval and temperament were found to be low to moderately heritable, at h^2= 0.17 and 0.14, respectively.

Repeatability

Since the data used to analyse kicked off teats (0-6) and milking interval were repeated records (one observation for every milking), repeatability (t) was calculated for these traits. Repeatability of NKO was estimated at 0.24 and the repeatability of milking interval at 0.61 (table 3).

Table 3: Estimates of heritability (h^2)with standard error (SE), genetic variance (σ_A^2) and repeatability (t) for the four traits.

Trait	h^2	SE (h^2)	σ_A^2	t
Number of kick-offs (NKO)	0.06	-	0.28	0.24
Proportion of kick-offs (PrKO)	0.31	0.003	0.01	-
Milking Interval (MI)	0.17	-	1.34	0.61
Temperament (TP)	0.14	0.076	0.18	-

Genetic correlations

Estimated genetic correlations between temperament scores and both kick-off traits as well as milking interval (Table 4). The three traits were all negatively correlated with temperament score. Between temperament and the kicked off teats (0-6) the correlation was strong, -0.46 which indicates that a higher temperament score, ie. a calmer cow, was associated with fewer kick-offs. The correlation between proportions of kick-offs and temperament was a similar, but slightly lower value.

They were moderately correlated, r= -0.36, which implies that a lower proportion of kick-offs, or a lower probability that the cow kicks off a teat cup, could mean that she would be expected to have a more favourable temperament. The genetic correlation between milking interval and temperament was found to be weaker (-0.24), indicating that a longer milking interval could suggest a less desirable temperament (a more nervous cow).

Table 4: Genetic correlations (r_g) and residual correlations (r_e) between the three traits analysed and temperament.

	Temperament Score	
Trait	**r_g**	r_e
Number of kick-offs (NKO)	-0.50*	0.18
Proportion of kick-offs (PrKO)	-0.38*	0.57
Milking Interval (MI)	-0.21	0.21

* significantly different from zero using a one-sided test at 5% level.

DISCUSSION

In AMS many variables related to of the animals are recorded and analyses can be difficult due to the sheer amount of data. However, as more and more farms convert to robotic milking, a method to make use of the data will be beneficial for improvement of the herd and eventually to improve the breed's suitability for automatic milking.

This is the first genetic study evaluating kick-offs recorded in an AMS. Other genetic studies that have been done using robot data include Nixon et al. (2009) and König et al. (2006) for milking interval, and Carlström et al. (2013) and Gäde (2007) who looked at milkability traits. Therefore, not much is known about kick-offs and interpretation of the results of the present study must be based on a combination of genetic and behavioural studies.

Phenotypic values

On average, 29% of the milkings had one or more kick-off(s). This is considerably higher than other studies, where 13% (Rousing et al 2006) and 19% (Kaihilahti et al 2006) of the cows kicked off a teat cup. The higher value in the present study could be due to that all the cows were primiparous as well as that the other studies were not done over as long a period time as the current study. Also, the brand of the robot can influence the measurement of kick-offs.

The average milking interval in the data was 9.72 hours which makes 2.47 visits per day. In other studies the milking frequency was similar. Lovendahl et al. (2011) observed an average of 2.71 visits per day in Holsteins. Two other studies reported cows visiting the AMU 2.70-3.05 times per day (different according to stage of lactation) (König et al. 2006) and 2.54 visits per day (Nixon et al. 2009).

Trait definitions

In this project, two different ways of estimating the genetic background of kick-offs were used in order to compare and contrast two different trait definitions. The first included data from every milking and was representative of cows who kicked off the teat cups more than once. The proportion of kick-offs trait (PrKO) is probably best thought of as a probability that the cow in question will kick off one or more teat cup(s) during milking. The latter could be more favourable because it minimises biases due to machine error or the cow having an off-day, and it is also a simpler trait to analyse. Many cows have a higher amount of kick-offs during the first few weeks of lactation (Figure 1) so this effect would be partially accounted for (although not as accurately as including every record with lactation stage as a fixed effect).

Milking interval was estimated using every milking record, as in Nixon et al. (2009). Other studies considered milking frequency on a daily basis (König 2006 and Lovendahl 2011). Carlström et al. (2013) reported that estimates were weak for number of milkings per day. They suggest that MI is a superior measurement of milking frequency. Therefore, although number of milkings was available on the cows in the study, we chose to use milking interval.

Heritability Estimates

The estimates for heritability of the two kick-off traits were starkly different and therefore we should contemplate the cause. The proportion trait had a much higher heritability and could be regarded as a better measurement. For instance, it is easier to think about how likely the cow is to kick off a teat cup corresponding to her temperament score than to consider every milking separately. Maybe on one day she is especially irritable or has pain in her udder and kicks off the machine six times, but this does not reflect her general temperament.

Even though the heritability of a single milking was low, the heritability of a large number of milkings would be much higher. However, repeatability (t) of NKO, which is often referred to the upper limit of heritability when having many measurements, was still lower (0.24) than h^2 for PrKO. Perhaps a more sophisticated random regression model (with respect to days in milk) would be better in handling the covariance structure over the whole lactation than the current simple repeatability model. It could also be possible to use PrKO only over the first 3 months of lactation, because breeding values could be estimated earlier.

Estimations of heritability for milking interval were similar to those found by Nixon et al (2009) (h^2 = 0.18) and König (2006) (h^2= 0.17). Heritability for temperament was estimated at 0.14 in the present study which is similar to the findings of previous studies (Table 1) and the routine genetic evaluation by NAV (NAV 2013).

Genetic Correlations

The genetic correlations between both definitions of kicked-off teats and temperament were large enough to indicate that the tendency to kick off teat cups is controlled by some of the same genes as temperament. It could also be said that cows that kick off teat cups more are considered by famers to have a poorer temperament and therefore given a lower score. As kicking off can cause failures in the milking robot, and can represent incomplete milkings, farmers would be likely to prefer cows that stand calmly in the robot until the milking is complete and in turn yield more milk. In one study, cows kicking either at the start of milking or during milking in an AMU were responsible for 84.5% of robot failures caused by a cow (Kaihilahti et al. 2006).

The genetic correlation of milking interval and temperament was, although just barely, not significant using a one-sided t-test. Further analysis of this trait is needed to determine if any solid conclusions can be made relating temperament and milking interval. However, breeding for a reduced milking interval would still be beneficial because of the low to moderate heritability.

Suggestions

The current system in use in Sweden and many other countries to evaluate temperament is very subjective, as it asks the farmer to evaluate his or her own animals and determine how easy they are to handle. Farmers could score their cows based on personal preference, or merely by comparing cows to each other. An objective way to score cattle would also get rid of between-herd bias.

Even though cows are very adaptable and able to learn to use an AMS rather quickly, selection of bulls based on their future daughters' suitability for AMS is needed. Preference will vary from farm to farm and differ especially between AMS farms and farms with conventional parlours. Evaluation of traits with AMS in consideration is especially important as the amount of AMS farms increases.

However, it probably would not be possible to completely satisfy both types of farms' needs with the national breeding scheme. Including kicked-off teats in the breeding goal would also be beneficial for cows milked in herringbone or rotary parlours, but milking interval would not be so applicable in those systems. Traits like milking interval which are only relevant in AMS herds may eventually need to have a weight in the breeding goal.

The proportion of kicked-off teats trait and milking interval could be included under the category workability, without abolishing temperament score. It is still very important to include farmers' personal preference from cows and what works best for them. Additionally, in an AMS farm, cows may be ignored, and when the farmer must evaluate his cows' temperament they receive more observation and this could keep the welfare standard high and fear of humans to a minimum. As recommended by Schutz et al (2001) further studies on the economic benefit of including new temperament traits in the breeding goal are needed. Although a value has been assigned to the temperament score rising or falling, it would be interesting to see how large the economic benefit would be of reducing kick-offs and shortening the milking interval.

As environment, especially early handling, influences temperament (Broucek et al. 2008) it is very important that this is emphasized in AMS farms. As farming becomes more automated, animals can become more accustomed to dealing with machine and less with man. The automation of milking and recording cow status cannot replace human attention to the herd. Further studies on how well animal welfare is maintained when converting to an AMS system are needed as well as how welfare and fear relate to temperament.

Workability, and more specifically temperament, is a trait not included in all countries' breeding goals for dairy cattle, especially those with more of an emphasis on yield. Deriving economic weights for temperament could justify inclusion or a heavier weight in the breeding scheme. Having cows that will take themselves to the milking box and then stand quietly while being milked can save a substantial amount of labour and keep the machine in good working order which ultimately leads to less labour and a reduction in time and expenses required for maintaining production. Furthermore, a well-functioning, cooperative herd frees up the farmer to spend more time on other aspects of cow management, e.g. reducing mastitis, ensuring good nutrition, and improving fertility.

CONCLUSION

Records from AMS have the potential to be used in genetic evaluations of dairy cows. Increased quantity of observations and automatic recording means that accuracy will improve and cost of genetic evaluation could hypothetically decrease. Objectivity of observations has the potential to replace old evaluation schemes which, for temperament, are based exclusively on the farmer's opinion of his or her cows. Using the estimate for a proportion of kick-offs during the entire lactation or the first few months, or in other words, the probability that the cow will kick off the teat cups each time she visits the milking robot, has the potential to replace or supplement the current evaluation scheme for temperament and in turn could improve workability of cows in AMS. This is a growing percentage of farms not only in Europe but also on other continents, and using automatically recorded traits would be especially favourable in bigger farms where each cow is not routinely paid attention to on an individual basis.

ACKNOLEGEMENTS

I would like to take the opportunity to thank my supervisors at SLU, Erling Strandberg and Karl-Johan Petersson for their assistance during this project. I would also like to thank Caroline Carlström for providing me with the data. My supervisor from the Norwegian University of Life Sciences, Bjørg Heringstad, has also provided valued assistance and worthwhile input so I would like to extend my thanks to her as well.

I would also like to thank the EMABG (European Masters of Animal Breeding and Gentics) programme coordinators, especially Birgitta Malmfors and Johan van Arendonk, for providing me with the opportunity and the financial support to study at two universities in Europe.

Last but not least I would like to thank my family and friends, both in Scandinavia and in the United States, for always being there for me (whether in person or not) with their unrelenting love and support.

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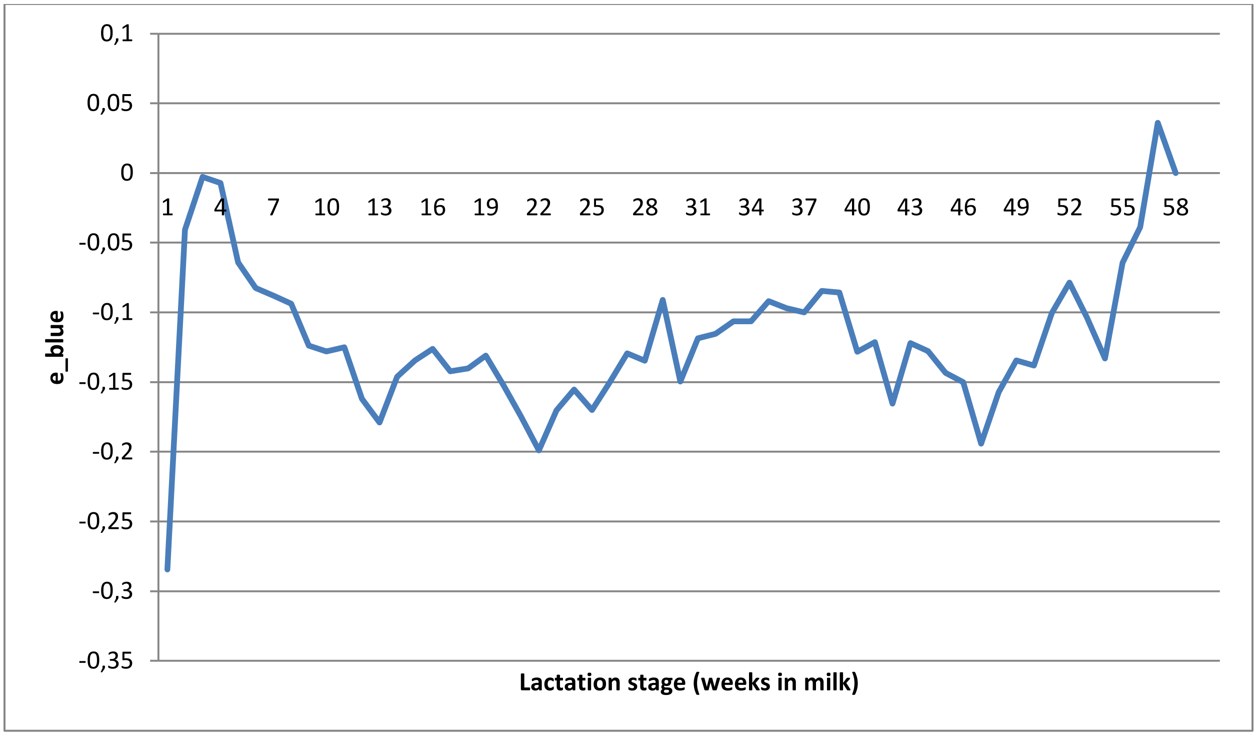

FIGURE 1: EFFECT OF LACTATION STAGE ON AMOUNT OF KICK-OFFS

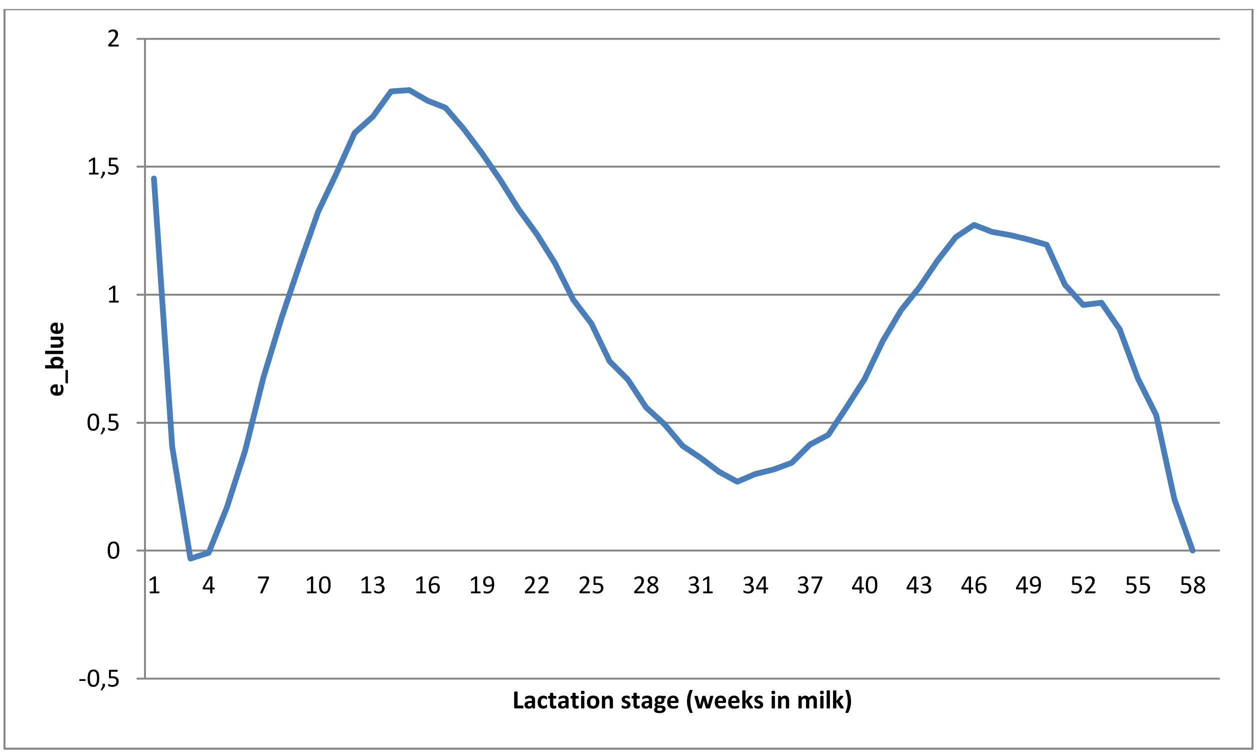

FIGURE 2: EFFECT OF LACTATION STAGE ON MILKING INTERVAL

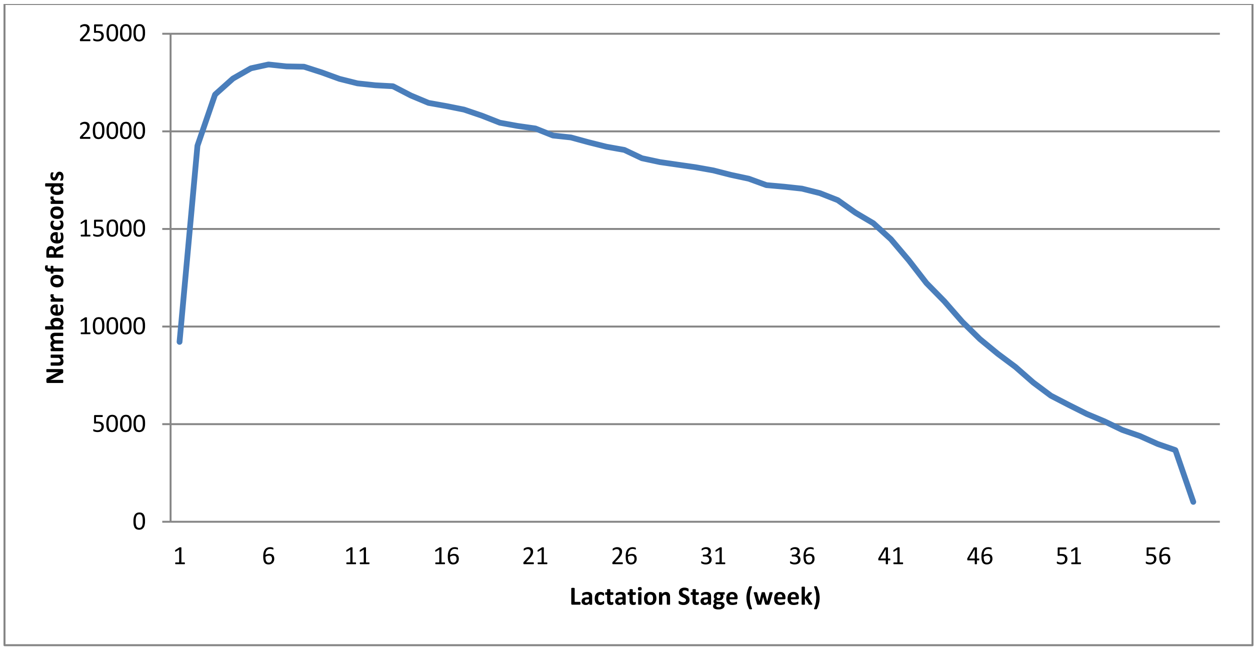

FIGURE 3: AMOUNT OF RECORDS OVER LACTATION