The use of a new sensor (Behaviour tag) for improving heat detection, health and welfare monitoring in different rearing conditions

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Abstract

The milk production increase of the individual cow and the growth in dairy cow herd size in the last decades are generating new challenges for health and reproduction performance in the modern dairy farms.

Detection of oestrus and early diagnosis of sick cows are important keys in the management of dairy farms. Monitoring the welfare and comfort of the cows is essential for health, reproduction and production of dairy farms and for the profitability of the herd.

A newly developed sensor, a Behaviour tag, which records rest and activity behaviour of cows, is already employed in research and commercial dairy farms. This paper review studies and observations performed in these farms, exploring the applications of the new recorded data.

Our observations support the assumption that incorporating lying behaviour data could improve heat detection under limited conditions such as tie stall barn and heat stress environment. Furthermore, lying behaviour is showing promising possibilities for improving the treatment of health disorders, by both specifying the disorder and reducing time for detection.

In a survey that was performed in 6 Israeli commercial dairy herds (1808 lactating cows), the dynamic of daily rest time versus daily milk production was explored. It was found that the correlation between those two parameters changes along the lactation with correlations of -0.846, 0.628, -0.706, -0.843 and -0.466 for 5-25, 26-50, 51-100, 101-200 and 201-305 DIM, respectively. Under the hot Israeli summer dairy cows spent less time resting compared to winter season (8.7 vs. 10.2 hours/day), this probably due to the heat stress and the intensive cooling procedures during the summer. The changes in rest time routine were found to be a sensitive tool for cow comfort assessment.

Our findings suggest that integrating automatically collected rest behaviour data to computerized herd management systems has high potential to monitor cow welfare and comfort and to improve of heat detection capabilities and early diagnosis of sick cows.

Keywords: Lying behaviour, cow, welfare, comfort, health, oestrus detection, pedometer.

1.0 Introduction

Increase of individual cow milk production and the size of the dairy cow herds in the last decades, generate new challenges for health and reproduction performance in the modern dairy farms. Detection of oestrus and early diagnosis of sick cows play an important role in the management of dairy farms.

Monitoring the well being of the cows is essential for health, reproduction and production of dairy farms and for the profitability of the herd.

Poor welfare usually leads to greater susceptibility to disease due to effects on the immune system as a function of having to contend with difficult condition (Broom and Corke, 2002). The OIE, Guiding Principles for Animal Welfare (O.I.E, Terrestrial animal health code, 2006) states that there is a critical relationship between animal health and animal welfare. Improving farm animal welfare can often improve productivity and food safety, hence leading to economic benefits.

Schefers *et al* (2008), have identified stressful condition such as stocking density of breeding or high group pens as a significant negative influence on the overall herd average conception rate (Cited by Cook, 2008).

Furthermore, animal welfare is of considerable and growing importance from the social, political, ethical and scientific viewpoint (Clamari and Bertoni, 2009).

Some authors suggest that among various animals' direct reactions - total lying time and lying synchrony are key factor of cow welfare (Fregonesi and Leaver, 2002). According to Jensen (2005), "dairy cows are highly motivated to lie for 12 -13 h/day". Mostly, authors define the rest target for a dairy cow as 12 -14 hours/day. Erroneous management, climatic factors and health problems often prevent achieving these goals.

In the last years, high efforts were invested in developing systems for evaluating animal welfare. Nevertheless, the current research apparatuses that evaluate animal welfare are expensive and time consuming (Sørenson, 2003 as cited in Ekman and Sandgren, 2006). For evaluating welfare and comfort status in commercial farm the situation is even more challenging. Different indices were developed but they are all subjective and based on visual observations, which require time and skilled labour. Bartussek (1998), stated about the ANI system, which grades important factors in animal rearing, that either no or very few animal based measurements or management variables are used in the currently systems used. Experiences from users indicate good repeatability in measurements at different visits and between different evaluators, but this does not mean that farms with the best or worst welfare are classified in the right category, or in other words, the validity of the index is not satisfactory (Cited in Ekman and Sandgren, 2006).

Tolkamp *et al*. (2010) suggest that information on (changes in) standing and lying behaviour of cows can be used for oestrus detection, early diagnosis of disorders and evaluation of welfare consequences due to change in housing and management.

The usage of time-lapse video-photography to monitor cows' behaviour is expensive, time consuming and inconvenient for commercial farms.

Recently, sensors fitted to cow leg were developed for monitoring activity and lying behaviour of cattle – The IceTag (Ice Robotics, Roslin, UK), ALT-Pedometer (Brehme *et al*., 2008), and Pedometer Plus^{TM} (S.A.E. Afikim, Israel). The latter is incorporated in the existing Afimilk dairy management system and Afifarm software and serves as a "Behaviour Tag".

The present paper discusses the use of this new tag for improving cow welfare and comfort, fertility (oestrus detection) and health (health problem detection).

This paper focuses mainly on the relevance of lying (rest) behaviour of cows as an indicator for cow welfare assessment. Despite the growing interest this area has for the milk industry (breeders, researcher and consumer), there is still lack of automatic objective tools for monitoring and evaluating the in farm status. The primary interest of the authors is to examine and evaluate the potential use of the Behaviour tag for improving management procedures and facilities at the herd level.

2.0 Pedometer Plus^{TM} system – Behaviour Tag

The Pedometer Plus^{TM} system (S.A.E. Afikim, Kibbutz Afikim, Israel) is a novel sensor that supplies three parameters: Activity (steps/hour), Lying Time (minutes) and Lying Bouts (changing position between standing and lying). The tag is fitted to the cow leg (front or rear), the data is accumulated and transmitted to management software (Afifarm^{TM}) each time the cow is passing an antenna (which could be located in the milking parlour, walkways or in the barns).The recorded data is analyzed and the information presented for the user. Fertility – improving heat detection

2.1. Current reproduction status in dairy cows

Reproductive efficiency in dairy cows is decreasing worldwide. This decrease is contributed mostly to the increase of milk production, but other factors also contributing include; increase in herd size, global warming, diets and others (Lucy, 2001; Sheldon and Dobson 2003). Lucy (2001) reviewed the decline in reproductive performance in many aspects – decline in first conception rate (CR) from approximately 65% in 1951 to 40% in 1996 in New York (U.S.A.) dairy cattle, and decrease of CR from 55% in early sixties to approximately 45% for insemination at spontaneous oestrus and 35% in timed AI in recent publication.

In addition, there is an increase in other reproduction parameters such as service per conception, open days and days to first insemination. The enlarging herds size and the intensive management increase the risk for mammary and uterine infectious which are risk factors for infertility in dairy cows (reviewed by

Lucy, 2001; Lavon, personal communication). The global warming which exposes more cows to heat stress for longer durations also contribute to the decrease of reproduction efficiency (Lucy, 2001).

Furthermore, oestrus behaviour, intensity and duration have reduced in the last decades (Mcdougl, 2006; Seldon *et al*., 2004). Lucy (2007) stated that anovulatory and behavioural anoestrus is one of the four primary mechanisms that depress fertility in lactating cows. Under limited conditions like heat stress, early period of lactation and tie stall barn oestrus behaviour is even more depressed, increasing the ratio of "silent oestrus".

Nebel *et al*. (1997) (Cited in Hansen and Arechiga, 1999) and DeSilva *et al*. (1981) reported that dairy cows in oestrus during the summer had 4.5-4.7 mounts per oestrus vs. 8.6-11.2 for those in winter, while Thatcher and Collier (1986) reported that the percentage of undetected oestrus periods in commercial dairy farms in Florida were estimated at 76%-82% during the hot season compare to 44%-65% in the cooler season (review by Hansen and Arechiga, 1999).

Heat detection ratio depend on the number of ovulation post partum, with much lower rates in the first ovulation compare to second and third (Peter and Bosu, 1986, cited by Frick *et al*., 2002). Ranasinghe *et al*. (2010) reported that incidence of silent ovulation was 55.2%, 23.8%, 21.3%, and 10.5% at the first, second, third, and fourth ovulations postpartum, respectively.

2.2. The importance of oestrus detection

Effective oestrus detection is essential for reproduction improvement (Foote, 1974, Frick *et al*., 2002; Gwazdauskas *et al*., 1982). Nebel *et al*. (2000) indicate that for the majority of dairy herds where artificial insemination is practiced, the limiting factor toward obtaining efficient reproductive performance is the failure to detect oestrus in a timely and accurate manner. The positive impacts of increased oestrus detection rates are: improved insemination results, controlled calving interval and total pregnancy rate (Stumpenhausen, 2001 cited by Frick *et al*., 2002). Frick *et al*. (2002) reviewed studies calculating a cost of 0.59-1.17 Euro per day of prolonged calving intervals and a cost of 1.52 Euro per cow per year for 1% decrease in CR. Annual losses to the U.S.A. dairy industry, due to oestrus detection failure or oestrus misdiagnosis, was estimated in more than US$300 million (Senger, 1994 cited by Nebel *et al*., 2000).

2.3. Oestrus detection in different rearing conditions

Frick *et al*. (2002) cited in their review, studies reporting difference in increase of activity during oestrus between cows kept in free stall barn and tied stalls. These studies report 14%-20% activity increase during oestrus in tie stalls compared to 93% of this increase in free stall. Cow in comfort stall housing changed their activity less distinct at the time of oestrus compare to cows in free stall housing (Kiddy, 1976). Studies using activity for oestrus detection in free stalls and loose stall barns were reported detection rate of 72% to 100%, with error rate of 17%-51% and specificity of 96%-98% (review by Frick *et al*., 2002), while in tie stall barns detection rates using activity behaviour were 59%-80% and high false positive alarms up to 1.2 false positive for every correctly identified oestrus reported (Kennedy and Ingalls, 1995; Redden *et al*., 1992). In a study conducted in Japan deferent methods (neck pedometer vs. leg pedometers and diverse algorithms for defined activity deviation) in different rearing conditions (pasture grazing, open paddock and tie stall barn) were tested to evaluate efficiency and accuracy of oestrus detection in heifers using activity data. The best results for open paddock were of 92% efficiency and 100% accuracy (hind leg) and results of 87% and 82%, respectively were found for heifers in tie stall (front leg) (Sakaguchi *et al*., 2007). These results are better than other studies probably due to the fact that heifers are showing enhanced external oestrus behaviour signals compared to cows, and the extenuating of defining correctly identified oestrus used in this study.

2.4. Improving oestrus detection by incorporate lying and activity behaviour

Early in the eighties of the last century it was suggested that measuring standing time and activity could be used for heat detection in tie stall barns. Walton and King (1986) reported that number of changes in postural position during the previous night increased on the day of oestrus, but their results were disappointed with more false positives than true positives events. Lately it was reported that cows in oestrus do not lie down for 6-17 hours and that cycles with weak oestrus intensity or quiet oestrus recognize by the ALT pedometer, very frequently show oestrus symptoms only under measuring parameter "lying time" (Brehme *et al*., 2008).

Based on these reports and on the authors observations in commercial farms equipped with the Pedometer Plus system (Figure 1) we speculated that the integration of both activity and rest behaviour (rest time and rest bout) could improve oestrus detection in unfavourable condition such as heat stress, tie stall or free stall barns and ovulation in early stage of lactation.

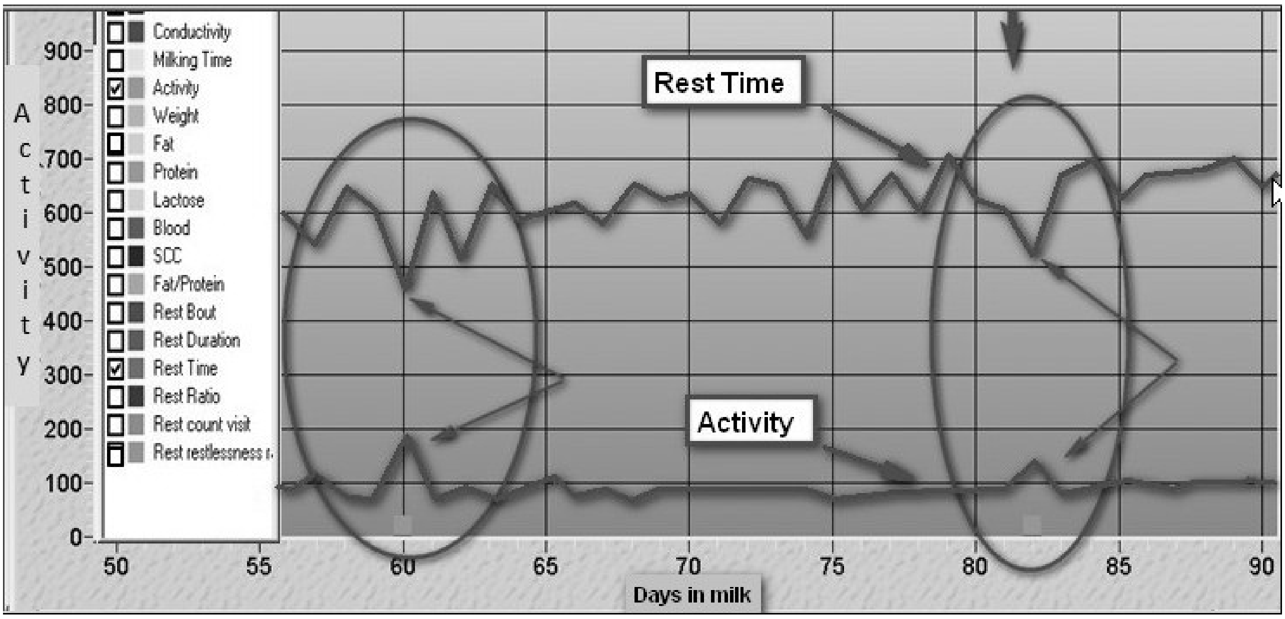


Figure 1. Example for two events (indicated by ellipses) of silent oestrus (low activity), detected based on integration of the slight increase of activity with parallel decrease in rest (lying) time.

Initial results from study conducted in a large commercial Israeli farm (~500 milking cows), containing both free stall and loose stall barns, during the summer of 2009 (Kaim, personal communication), show difference of +5.2% of efficiency oestrus detection rate between cows housed in the loose barn compared to free stall barn when only activity measurements were analyzed.

Currently models for improving efficiency of oestrus detection with respect to cow housing are being constructed. These models are being constructed from the integrated lying and activity data for different housing particularly for tie stalls. Figure 2 illustrates an example of an oestrus event detected for a cow in tie stall housing using integrated data of activity and lying behaviour.

The data presented in Figure 2 are in full agreement with those obtained by Brehme *et al.*, (2008).

3.0 Health – early detection and prevention of health problems

3.1. Rest behaviour as a potential tool for early detection of disease and health improvement in dairy cows

There are numerous studies describing the correlation between lying time and health status of the cow, and the importance of adequate rest time for cow health in general and for the hoof health in particular (Broom and Corke, 2002; Cook *et al.*, 2004; Fregonesi *et al.*, 2006, Grant 2005; Grant, 2007; Grant 2008; Jensen *et al.*, 2005).

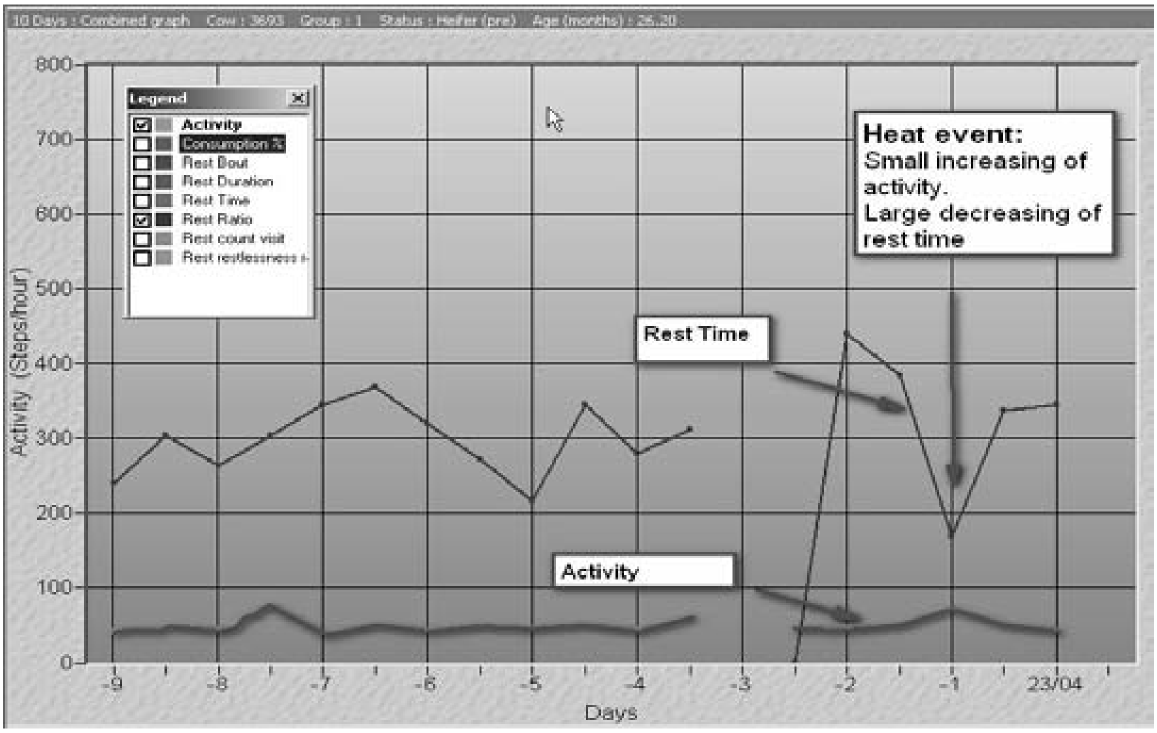


Figure 2. Example of oestrus behaviour (large decrease in rest time with simultaneously small increase in activity) of heifer housed in tie stall barn.

It was suggested that identification of lying and standing bouts may provide information on animal behaviour that may assist in early detection of health problems (Tolkamp *et al*., 2010). Nevertheless there are limited works studying the use of lying behaviour for health problem detection. This is probably due to the difficulty of continuously measuring and monitoring such behaviour for prolonged time on large number of animals. Niss *et al*. (2009) reported that disease induced by oligofructose overload (i.e. ruminal acidosis and lameness) can effect lying behaviour in heifers. They concluded that both metabolic and leg problems appear to lead to a thwarting of the lying down motivation in cattle and potentially prevent the animals from lying down. Blackie (2008) reported that cows locomotion score 3 (1-5 scale) spent approximately 2 hours/day longer lying time than cows with locomotion score 1 and 2. Juarez *et al*. (2003) reported that the percentage of cow's lying time increased linearly with the increase of cow's locomotion score. Other publications supply the correlation of activity data (not including lying behaviour) with fresh cows disorders and lameness (Edwards and Tozer, 2004; Mazrier *et al*., 2006).

Veterinary treatments and management changes are generally more effective when initiated at earlier stages in the disease process. Therefore, early identification of sick animal could improve animal welfare and reduce treatment cost (Gonzalez *et al*., 2008). Gonzales *et al*. (2008) declared that under the intensive condition of the modern dairy farm, tools to monitor the health status of cows can assist breeders to identify sick cow earlier. The implementation of such tools via computer-controlled programs can became valuable instrument for on-farm use.

3.2. Using the Pedometer Plus system for early detection of health problems

Our observations in commercial farms show that there is a wide diversity in individual cow response to different disease and painful events. Some disease such as abdominal pain or clinical mastitis can cause an increase in rest bout numbers and a decrease in the duration of each lying event (Figure 3). This is probably due to the pain and discomfort inflicted on the cow placing its body weight on the painful area, belly or udder, respectively. If the cow becomes too exhausted long lying durations are expected even at high pain levels during the recumbence time. Lame cows tend to lie-down for longer periods although in some cases a cow will prefer not to lie-down at all, because of the pain and suffering during the standing up and lying down process. Some of the events can be detected by using integrated data of rest behaviour, activity, milk production, milk conductivity, milk components (namely; fat, protein, lactose and blood) and body weight, measured by the integrated Afimilk system, while other events could be detected only by the changes in the rest behaviour. Figure 4 demonstrate a pre calving heifer diagnosed by the herdsman as suffering from eye injury, following changes only in lying behaviour, detected by the Pedometer Plus system.

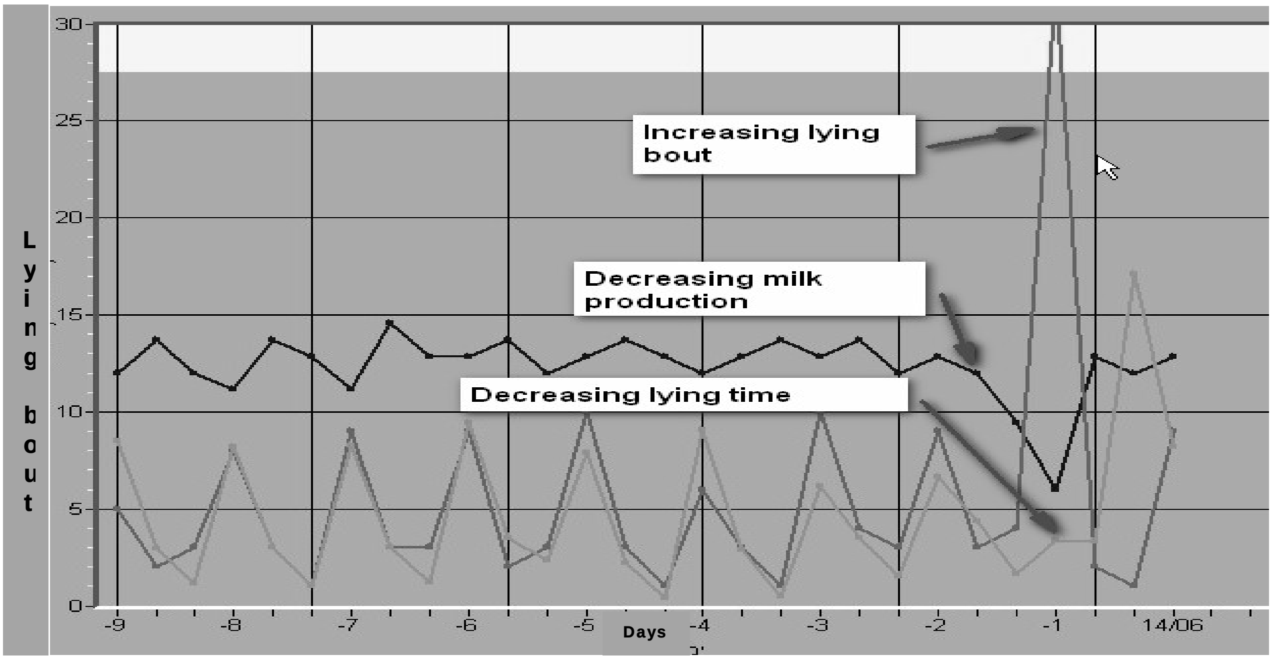


Figure 3. Changes in lying behaviour (lying time and lying bout) and milk production of cow suffering from abdominal pain (high increasing in lying bouts probably due to discomfort and pain during the recumbency).

Several studies, aimed to explore and define the characteristic behaviour of specific diseases (lameness, mastitis, calving disorder, ketosis, acidosis and digestive problems) are currently conducted.

The objective of these studies is to integrate behavioural data with additional parameters (milk quantity, milk conductivity, milk components and body weight) to improve detection of health disorders, and reduce time for detection.

4. Welfare - Can cow behaviour be used as an objective measurement for evaluating cow welfare and comfort?

4.1 Welfare assessment

Animal welfare is a term that includes many different aspects which cannot be described by one definition. Calamari and Bertoni (2009), based on Fraser and Broom (1990) suggest that "level of welfare is not achieved merely by the absence of difficulties..., but by the herdsman's capacity to overcome them through genetics, **management**, feeding, hygiene, social environment, etc".

Based on Calamari and Bertoni (2009), welfare assessment model for livestock herd can include two types of measures:

1. Environmental parameters - describe the production and management system (e.g. feeding and drinking facilities, housing and bedding condition, etc.) – these parameters are **indirect indicators**, they are relatively easy, quick and reliable to record, nevertheless these indicators leads to "risk assessment", but not to an evaluation of their real effect on welfare status, which can be differ in different systems.

2. Animals' reactions to specific environments - these parameters include behaviour, health and physiology data. Animals' parameters are **direct indicators**, they provide information on current welfare status, but in the other hand they do not point out the cause of impaired welfare.

In this section we examine the relevance of dairy cow behaviour (namely – activity, rest time and rest bout) as an indicator for the cow welfare and comfort status.

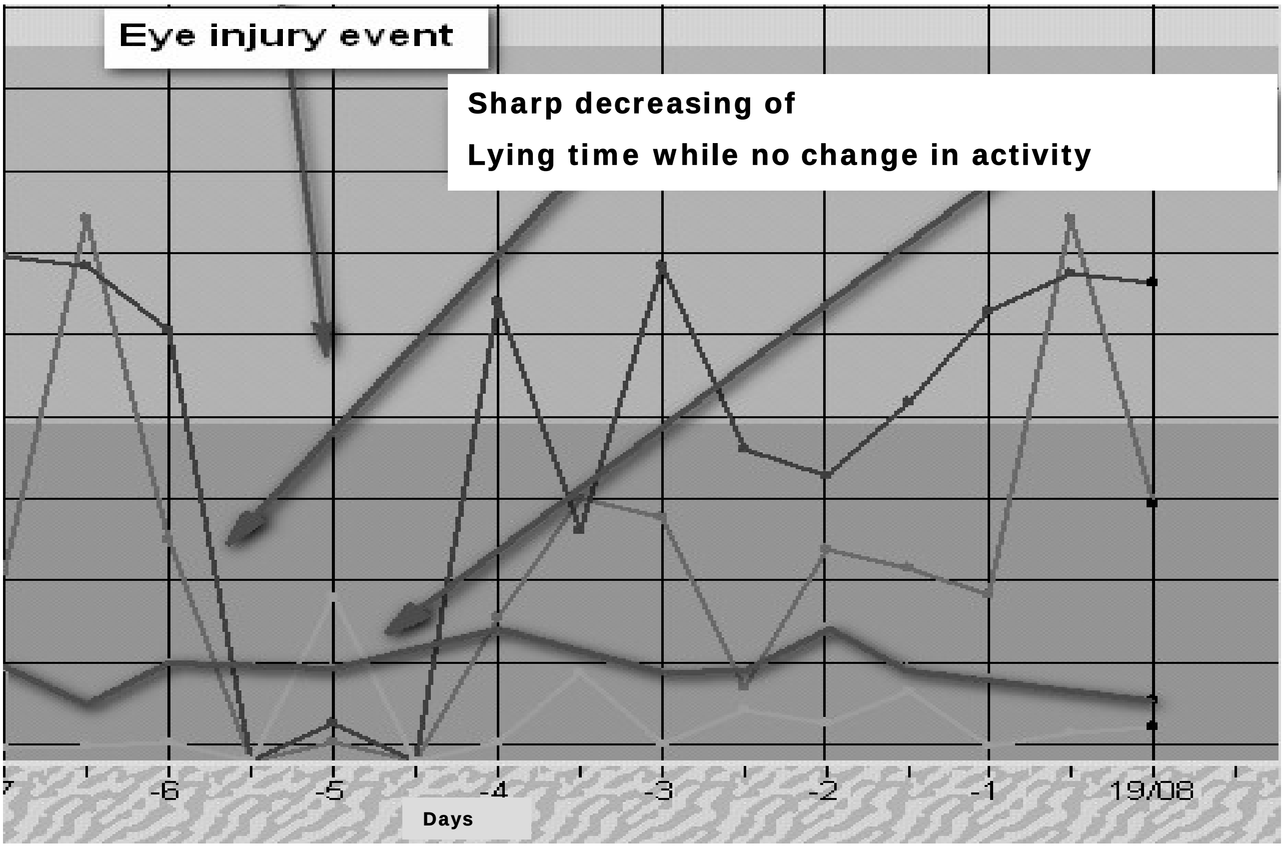


Figure 4. Changes in lying behaviour with no change in activity behaviour of pre calving heifer suffering from injury near her eye (note the recurrence for normal lying behaviour flowing treatment that was performed on day -5).

4.2. Are dairy cows' activity and rest behaviour recordings by the Pedometer Plus™ system suitable indicators for welfare status?

Once a new indicator is explored for its suitability to indicate any phenomena/status it is necessary that two properties are accomplished (Calamari and Bertoni, 2009):

1. Validity – the degree to which measurement actually measures what is supposed to.
2. Reliability – the variance between measurements.

In addition three other properties are desirable:

1. Feasibility – to be easily operated by trained people, to require limited time to be measured and to be cheap (Calamari and Bertoni, 2009).
2. Reduce the effects of mediation or interpretation of the data by people (herdsman, researchers and consultants).
3. Automatic monitoring 24/7.

4.2.1 Do cows' activity and rest behaviour supply information on cow welfare status (Validity)?

Deprivation of lying from cows was associated with increase in cortisol concentrations, reduced responses to ACTH challenges (Fisher *et al*., 2003; Munksguaard and Lovendal, 1993, both cited by Fregonesi *et al*., 2007) and increase in ACTH concentrations (Munksgaard and Simonsen, 1996). Cook (2008) summarize that a failure to achieve adequate rest is causing a significant stress response.

There are numerous studies that demonstrate the relationship between rest time and prevalence of lameness and hoof problems in dairy cows (Blackie, 2008; Cook *et al*., 2004; [Galindo and Broom, 2000;

Hassel *et al*., 1993; Philips and Schofield, 1994; all cited at Fregonesi at al., 2007]). Other studies indicate that rest time has higher priority for dairy cows when compared to feeding and socializing interactions (Batchedler, 2000; Metz, 1985, both cited by Grant, 2005; Munksgaard *et al*., 2005).

A study performed using the Pedometer Plus system by Livshin *et al*. (2005), concluded that a lying sensor can serve as indicator for suitability of housing condition and animal comfort. It was also stated that lying behaviour for individual dairy cows can indicate cows comfort in different housing conditions and physiological status. Drissler *et al*. (2005) and Tucker and Weary (2004) measured the effects of different housing and bedding condition on lying behaviour in aim to identify the most comfortable system.

Fregonesi and Leaver (2001) concluded that total lying time, lying synchrony, milk cell count and locomotion score are potential indicators for assessment of dairy cow welfare in different housing environments. Furthermore Weary and Tucker (2003) referred to Healy *et al*., (2000) work, summarized: "that this study provides some insight into behavioural measures likely to change if cow is uncomfortable, namely, time spent lying and standing, and the number of times she changes position between lying and standing".

4.2.2 Is the Pedometer Plus system a reliable method for recording activity, lying time and bouts?

Validation study of the system was performed at the University of Guelph, (Guelph, Ontario, Canada), it was concluded that the Pedometer Plus device appears to be a useful tool for the measurement of activity, including steps taken, number of lying bouts, and duration of lying time in dairy cows (Higginson *et al*., 2009).

The use of Pedometer Plus system allows recording data 24/7 with no time consuming and with minimal interpretation needed.

4.3 Review of studies and observations for evaluating dairy cows' welfare and comfort performed by means of the Pedometer plus system

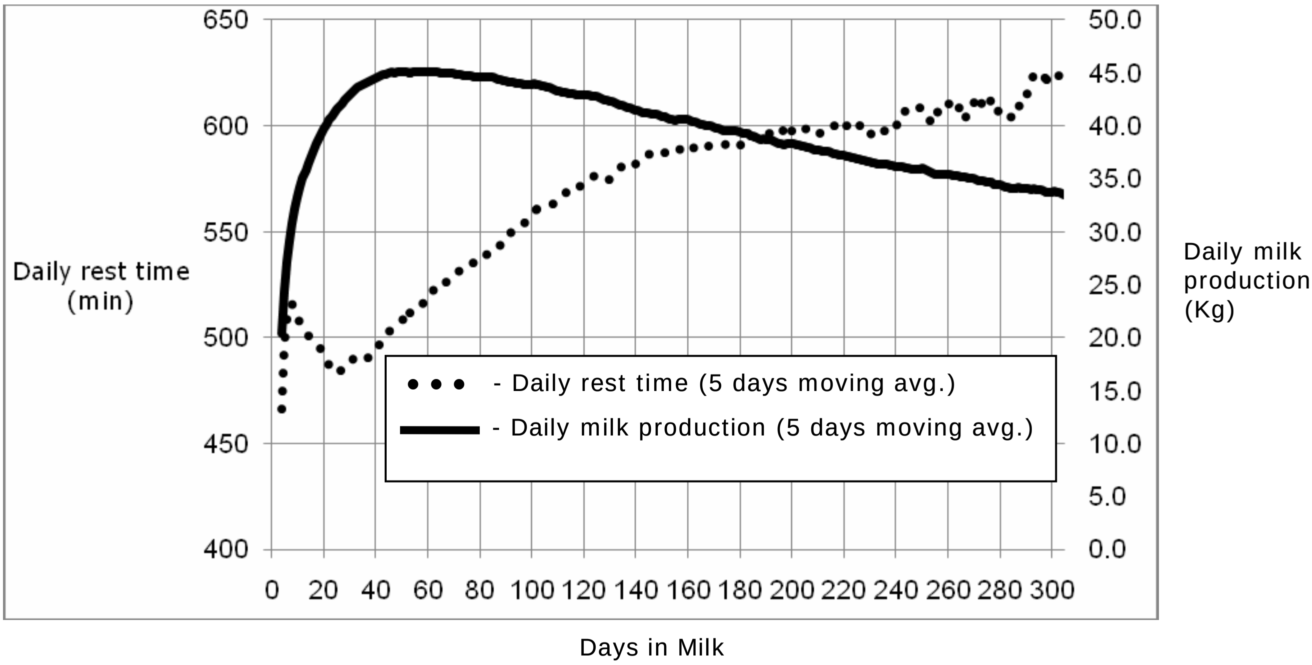
4.3.1 Survey of dairy cows' rest behaviour in Israel

A survey of Israeli commercial dairy farms, using the Pedometer Plus system for at least one year, was performed. The aim of the survey was to explore the rest behaviour of high producing dairy cows in the Israeli climate and intensive management conditions. Two aspects were analyzed:

1. The rest behaviour characteristic during the 305 days lactation.
2. The difference of rest behaviour between different times of the year (winter vs. summer) in the Israeli hot summer climate.

4.3.1.1. Characteristic of rest behaviour during the lactation

Data of daily rest time and milk production was collected from more than 1800 lactating cows in 6 Israeli herds from different geographic locations and varied sizes (range: 87 to 580 milking cows/farm). The average lactation graph of all cows is presented (Graph 1). Typical rest behaviour shows a decrease in rest time during the first 25 DIM, flowing by a sharp increase of daily rest time up to 150 DIM. A continuously yet more moderate increase occurs from 150 DIM and up, with highest rest time of about 10.5 hours/day at 305 DIM.



Graph 1. The dynamics of daily rest time (minute) of Israeli-Holstein cows versus daily milk production (Kg) during the lactation. The displayed values represent average data obtained from 1810 lactating cows (from 6 herds) with an average production of 11,832 kg milk /lactation, during 2009-10.

The authors suggest, that the decrease of the daily rest data in early lactation indicates the discomfort of many highly yielding cows during the metabolic stress, accompanied by the sharp increase of milk production during this stage in lactation.

In the aim to explore the relationship between milk yield and rest time and based on our finding regarding the dynamics of rest behaviour during the lactation, the lactation period was divided to five sub-periods; 5-25, 26-50, 51-100, 101-200 and 201-305 DIM. It was found that the correlation between daily milk yield and daily rest time changes along the lactation. The results are presented in Table 1. It can be seen that during the early stage of lactation there is negative correlation. While milk yield is increasing sharply there is a decrease in rest time. As it was described, this may be due to the "metabolic stress" the cows suffer from the high demands of producing milk. In the next period, 26-50 DIM, there is positive correlation were the cows overcome the "metabolic stress" while milk yield is still increasing. From 50 DIM and up to 305 DIM the correlation is inverted again and daily rest time is increasing continuously while milk yield is decreasing. The largest correlation was found to be in the periods of 5-25 DIM and 101-200 DIM (-0.846 and -0.843, respectively). The smallest one was in the period of 201-305 DIM (-0.466). The results were highly significant for most of the periods in all the farms but farm 5 (the smallest farm). The reason for that is not known. Data from this farm was excluded from the average calculations.

Table 1. Pearson correlations between daily lying time and milk yield during different stages of lactation in 6 Israeli dairy farms (range: 87 to 580 milking cows/farm).

	Pearson Correlation						
DIM	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Average[1]
5-25	-0.580[b]	-0.886[b]	-0.886[c]	-0.952[c]	-0.138	-0.924[c]	-0.846
26-50	0.291	0.677[c]	0.547[b]	0.871[c]	0.231	0.756[c]	0.628
51-100	-0.652[c]	-0.707[c]	-0.827[c]	-0.536[c]	-0.237[a]	-0.807[c]	-0.706
101-200	-0.726[c]	-0.795[c]	-0.898[c]	-0.948[c]	0.134	-0.848[c]	-0.843
201-305	-0.586[c]	-0.668[c]	0.041	-0.537[c]	-0.322[c]	-0.581[c]	-0.466

a=$P<0.1$, b= $P<0.001$, c= $P<0.0001$ [1] – Pearson correlation parameters of farm 5 were excluded.

Our observation is in agreement with other works, which found that lactating cows 6 weeks post parturition spent less time lying compared to 12 weeks post parturition (Blackie *et al.*, 2006) and that cows in early lactation spent significantly less time lying than those in late lactation (Bewley *et al.*, In press). Nevertheless to the authors' knowledge this is the first work to describe the dynamics of rest behaviour during the entire lactation of such a large population of dairy cows.

4.3.1.2 Characteristics of rest behaviour during different times of the year (winter vs. summer) in high yield cows under the Israeli climates condition (heat stress during the summer)

The rest behaviour and the milk production in 7 Israeli high producing dairy farms were investigated. All farms conduct three milking sessions a day. The farms are located in different geographic regions and climate conditions. Data was collected during three month of winter and three month of summer (January-March 2009 and July-September 2009, respectively) (Table 2). It was found in all farms that during the summer the cows rest less time (in average 88 minutes less) and produced less milk (in average 3.96 kg/day). The reasons for the decrease in rest time is probably mainly due to cooling management which in most of the farms is done before and between milking in the holding pen, restricting the available rest time. However, when comparing between individual farms it seems that some farm overcome this obstacle better than others, suggesting that management procedures are an important factor in increasing rest time. The higher coefficient of variation (CV) of rest time during the summer compared to winter time (6% vs. 4.25%) could be another indication of the influence of different cooling and management strategies treating this phenomena (the reasons for the decrease in milk is not discussed in this paper).

Table 2: Average daily rest time (hours) and milk yield (kg) in 7 Israeli dairy cow herds during winter (January-March, 2009) and summer (July-September, 2009).

	Daily Rest Time (hour)		Daily Milk Yield (kg)		Ratio Summer:Winter* (%)	
	Winter	Summer	Winter	Summer	Rest time	Milk yield
Farm 1	9.53	7.91	39.37	35.65	83	91
Farm 2	10.05	8.86	41.21	37.75	88	92
Farm 3	10.05	7.91	37.41	33.44	79	89
Farm 4	9.85	8.91	36.66	33.84	90	92
Farm 5	10.42	8.94	40.53	37.94	86	94
Farm 6	10.90	9.07	36.82	31.72	83	86
Farm 7	10.05	9.03	38.17	32.13	90	84
Average ±SD	10.12 ±0.43	8.66 ±0.52	38.60 ±1.81	34.64 ±2.53	86±4.25	90±3.41
CV (%)	4.25	6.00	4.69	7.30	4.94	3.79

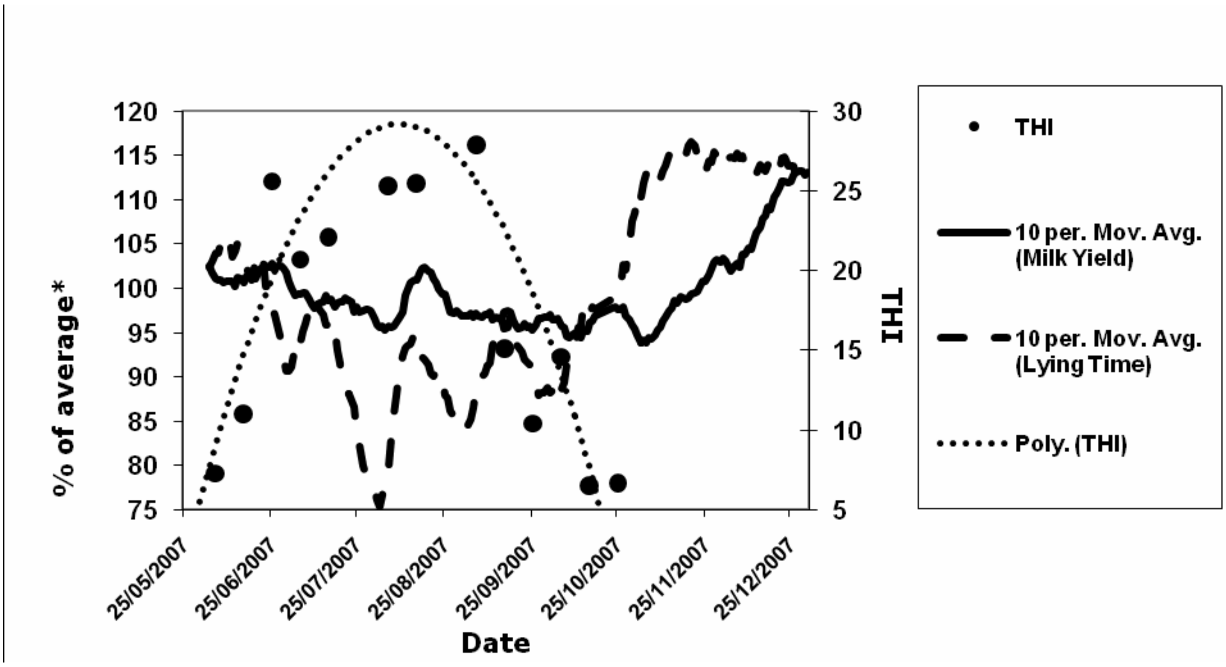
*Ratio Summer: Winter – the ratio between daily rest time or milk yield in the summer compared to winter, calculated as = (summer parameter/winter parameter)*100

It was found that in farms under similar heat stress conditions, equal temperature humidity index (THI) levels, there was a significant difference in rest time during the summer (data not presented), this is probably due to differences in cooling strategy and facilities used in the farms.

The reduction of rest time during heat stress is in agreement with other studies (Cook *et al*., 2007; Lee and Hillman, 2007; [Shultz, 1984 and Zahner *et al*., 2004 both Cited by Cook *et al*., 2007]).This reduction was attributed to increase in standing time which provides a thermal advantage, due to increase surface area for cooling while standing (Lee and Hillman, 2007). When the in diurnal rest behaviour of one farm was examined, it was found that during the summer the cows rest less time during the day (light hours) compared to winter (18% of available time vs. 34%), while in the night (dark hours) cows rest for longer time (65% of available time vs. 55%) in the summer. These findings suggest that the reduction of rest time during the summer is due to the large decrease during day time, because of the heat stress and the intensive cooling management. The cows tried to compensate for this reduction by increasing rest time during the cooler and quiet hours at night.

Based on observations in the farms, it was speculated that rest behaviour is a more sensitive indicator for cow welfare and comfort than milk production, and deviations in this behaviour will precede changes in milk production at the herd level. This speculation was confirmed in many events. We explored the time relation between daily milk production (kg/day) and daily rest time in a commercial farm comprising 68 milking cows with an average of 12,708 kg milk/cow/lactation during the summer (2007). The results are presented in Graph 2. It can be seen that under heat stress conditions (indicating by THI data) the negative change rate of lying time was more excessive and appeared earlier to the decrease of milk yield.

With the end of the hot season the lying time increased rapidly to the maximal steady level, followed by the increase of milk yield which took much more time to restore.



Graph 2. Changes of daily milk yield (kg) and lying time under heat stress conditions (data from 68 milking cows, average milk yield 12,708 kg milk/cow/lactation, May-December, 2007).

*Data of milk yield and lying time is presented as percentage of ten days average from the average of the entire period.

In future studies, different cooling methods and strategies will be explored using the lying time and rest behaviour as indicative parameter for the comfort of the cows.

4.3.2 Studies and observation for incorporating the Pedometer Plus system as a tool for evaluating cow welfare and comfort

In the last three years the Pedometer Plus system was installed in some research and commercial farm. Some of the studies and observations performed in those farms are reviewed below.

Adin *et al*. (Personal communication) tested the influence of increasing stock density of high yield dairy cow in loose stall barns. Cows in higher density (14.8 m^2/cow vs. 19.4 m^2/cow) rest 72 min/day less than the control group. It was also found that there were higher standard deviation (SD) values in the number of rest bout for the cows in the higher density group. It is the authors speculation that these higher SD values could indicate that some cows in that group (sick cows, low hierarchy) are influenced more by the high density than others (sound cow, high hierarchy). This speculation is based on other studies which demonstrate that young cows (primiparous) and lame cows suffer more when overcrowding compared to older cows (multiparous) and healthy cows (Grant, 2007).

Guash and Bach (2009) studied found a decrease of lying time and increase of activity when cows were moved from pens. These changes were more pronounced in primiparous than in multiparous cows and could be observed up to 4 weeks after the move.

Maltz (2006) investigated the effect of twice daily forced cooling (each one for one hour) management on the rest behaviour of milking cows. He reported that forced cooling cows for one hour twice daily during the summer does not impaired quantitatively with normal cow behaviour. These findings support our intuition that incorporating lying behaviour for evaluation of different cooling managements, could lead to a strategy that will improve heat stress relief with minimal interference of cows rest needs.

In one commercial farm using the behaviour tags, it was found that the rest time of three groups of cows housing in a free stall barns was much lower when compared to cows in adjacent loose stall barns. In the same day the bedding in those three barns was treated, and a sharp increase (from 420 minutes/day up to 500 minutes/day) was observed in less than one week (Figure 5).

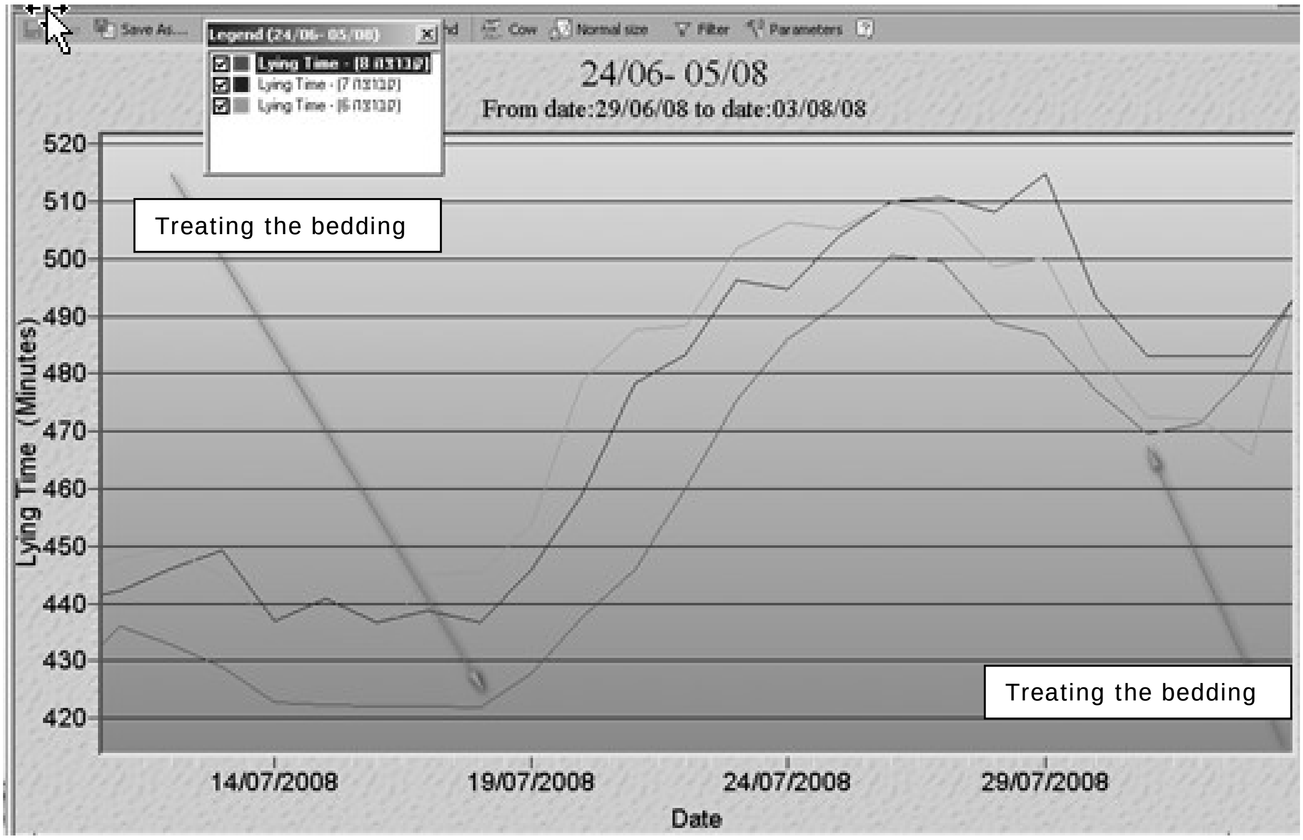


Figure 5. Extensive increase in daily rest time of cows in three free stall barns due to improving of the bedding (~500 milking cows commercial farm, south of Israel, July 2008).

This observation and others (not presented) support the highly potential use of automatic rest behaviour recording as a powerful management tool for monitoring and improving cows comfort and welfare status in commercial farms.

5. Discussion

The modern dairy farms introduce new challenges for breeders, veterinarians and consultants in all aspects of the dairy industry (management, housing, nutrition, reproduction and etc.). Reproduction performance and health problem of dairy cows have been two area of high interest for the dairy industry for long time and have been studied for many years. Yet, the results in many farms are not satisfying. Cow welfare and comfort is a relative new area of interest. Significant amount of research performed in the last two decades emphasize the importance of this topic for the productivity, fertility and health of the individual cow and overall herd performance.

Lying behaviour of cows provides valuable information which could be useful for improving oestrus detection in unfavourable conditions. In addition, this data can enable early detection of health problem and diseases, and be applied for monitoring cow comfort as an indicator of the facilities and management procedures in the herd.

The introduction of a new commercial "Behaviour Tag" (Pedometer Plus^{TM}, S.A.E. Afikim, Israel) which records activity and the rest behaviour (rest time and rest bouts) of each cow 24 hours/day, and the integration of this newly data in a computerized farm management system open new opportunities for herd managers and researchers.

Data that has been collected in commercial and research farms using the Pedometer Plus system illuminates the high potential of this system to improve oestrus detection performance and early detection of health problems. Furthermore, integrating of activity and lying behaviour data (particularly the latter), could be used for developing objective and automatic parameters for a cow comfort assessment system. This system will comprise the advantages of the automated recording of reliable data 24 hours a day on the overall individuals comprising the herd. Furthermore, the integration with other data collected by the herd management system (milk quantity, milk conductivity, milk components and body weight) has the potential for improving and fine tuning the assessment system.

The automatic daily monitoring of lying behaviour in 7 Israeli dairy farms enabled us to reveal: 1) the dynamics of cows' lying behaviour in different seasons of the local climatic condition; 2) the dynamics of the cows' lying behaviour along the entire lactation; and 3) the changing relationship between the lying time and milk yield in different stages of lactation. It was found that changes in routine lying behaviour of cows are more sensitive and provide earlier indication of cow welfare disturbance than changes in milk production.

Additional studies are required to develop easily operated models for herd managers and breeders, and to explore methods for optimization of rest behaviour in high producing dairy cows under the intensive conditions of modern farms. This last area of studies, will have to focus on investigating improvement of housing and other facilities conditions as well as management procedures like; cooling, mass treatments, feeding protocols and the timetable of these procedures in the daily farm routine.

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