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ADAPTABILITY OF DAIRY COWS TO ROBOTIC MILKING: A REVIEW

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ABSTRACT

Robotic milking systems (RMS) offer an innovative approach to improve productivity on dairy farms. RMS will influence the future growth of farms, the nature of husbandry employed and the quality of life on family farms. For farms using hired labour and located near industrial centres, RMS may contribute to the reduction of wage costs. As this technology is very expensive, and little is known regarding its interplay between animal, technology and stockman, or the effects on milking performance the detailed study is very required. Behavioural observation of the animals and monitoring of the system become extremely useful. In this review, the RMS impact on dairy cows is explored. What is the basis for adapting to the dairy cow milking is discussed in the first part of this review. Some housing parameters related to structures, design and environment are reviewed. Behavioural requirements of cows for robotic milking are written in the second part. The third part highlights the anticipated problems and last part is devoted to adaptability of cows to robotic milking. Recent studies on the impact of automated milking, different management regimes, and relocation with milking manner change on behaviour of dairy cows are discussed. The effects of inadequate milking procedures and improper milking technical parameters on welfare and udder health of cows are also emphasized.

Key words: dairy cow; robotic milking; housing; behaviour

INTRODUCTION

Husbandry intensification is often believed to lead to a reduction in animal welfare. We understand that every type of housing system must provide conditions conducive to comfort, good health, growth and performance at all stages of the animal's life. Automatic milking systems or robotic milking systems (RMS) offer an innovative approach to improve productivity on dairy farms. As this technology is very expensive, and little is known regarding its interplay between animal, technology and man, or the effects on milking performance, the detailed study is very important. Behavioural observation of the animals and monitoring of the system become extremely useful.

There is no doubt that RMS has become an important practice in dairy production. An increase of desire for a social life and more freedom has led many farms to take advantage of a new technology. Two-thirds of farmers think that a better social life is their reason for investing in an RMS (Mathijs, 2004). 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 and Western Europe as the farms are at suitable size.

In 1992, the first commercial milking robots came into use. Since 2000, RMS have substantially increased in popularity, and as in 2012, there were more than 10 000 farms in 25 different countries using RMS. Swedish and Dutch factories (Alfa Laval and Lely)

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had sold more than 19 500 robots by the end of 2012. In the Czech Republic 170 robots have been working. However, the Slovak Republic lags far. At present there are only 16 robots.

Robotic milking is a suitable solution also for large dairies, as there are several examples of successful dairies working under different conditions around the world. While technology costs go down, labor costs go up. This irreversible trend has affected most industries, and dairy is no exception. Automation will be the sustainable solution of the future. In addition to lower labour requirements, RMS results in a 5-10 % increase in milk yield which is mainly due to the increased milking frequency (Ketelaar de Lauwere *et al*., 2000; de Koning, 2010).

Milking, milk yield, milk quality, cow traffic, behaviour, and coping on environment are essential elements of RMS. When evaluating the performance tests, we focus not only on milk yield and milk quality, but also to changes in live weight of dairy cows and of course on health. There is limited information of behavioural factors associated with change of milking system after relocation of lactating dairy cows. Therefore, we focused on a detailed assessment of the adaptation of dairy cows to RMS.

The basic assumptions for use

Undoubtedly, automatic milking changes many aspects of farm management since both the nature and organization of labour is altered. Manual labour is partly replaced by management and control, and the presence of the operator at regular milking times is no longer required. Cow management including routing within the barn, the opportunity for grazing and the use of total mixed rations is altered. A high level of management and realistic expectations are essential for successful adoption of automatic milking.

When the cow enters the milking station (encouraged by highly palatable feed in the milking station), an ID sensor reads the cow's identification tag (transponder). These data go to the computer. If the cow was milked recently, the automatic gate system would send it out of the unit without access to feed or having been milked (Mihina *et al.*, 2012). When a cow milking is allowed and cow walks in the RMS to be milked, a 3D camera and laser technology helps the robotic arm to track the cow's movements and locate each teat. It attaches the teatcups and then starts milking each quarter at a time, adjusting the pulsation ratings for each quarter. This results in both optimal milking and more gentle experience for the cow (André *et al.*, 2010). Facilities for teat cleaning and separation of abnormal milk are incorporated into the automatic system and several adaptations are needed to accommodate continuous milking. RMS-systems are also equipped with sensors to observe and to control the milking process. Data are automatically stored in a database and the farmer has a management program to control the settings and conditions for cows to be milked. Attention lists and reports are presented to the farmer by screen or printer messages.

Visual control of cow and udder health at milking is, at least partly, taken over by automatic systems. The farmer's presence at regular milking times is no longer required. The nature and organization of farm labour changes such that manual labour dealing with milking is largely replaced by management and control activities. Regular visual checks of cow and udder health during milking are taken over by automated monitoring using smart sensor technology.

Well-functioning cow traffic is a prerequisite for a successful RMS. This includes an optimal number of visits both to the feeding area (number of meals) and to the RMS for all cows in the herd when cows are kept indoors, as well as during grazing. Cows housed in a free stall barn with voluntary visits to feeding and milking areas develop individual patterns of eating and diurnal activity over time (Melin *et al.*, 2005).

After visiting the milking system, the cow should have access to the feeding area. In "forced traffic" systems she has to pass the milking system in order to get access. In "controlled traffic" systems one-way-gates, with cow identification and selection capabilities, restrict cows to go directly to the feeding area only when the interval since the last milking exceeds the pre-set minimum.

Behavioural requirements of cows for robotic milking

Cow needs to have good locomotion (Tongel and Broucek, 2010; Micinski *et al*., 2010; DeVries *et al*., 2012). Voluntary cow movement has a strong influence on robot utilization (Holloway *et al*., 2014). The introduction of RMS brings about a significant alteration in the way cows are milked; no longer are they driven to a parlour by the farmer, but they walk to the RMS on their own accord. Moving of cows, which increases labour requirement, should be minimalized. Cows must make their own way to the milking unit and stand quietly while being milked. This requires emphasis on traits, especially temperament (Adamczyk *et al*., 2013; Broucek *et al*., 2008).

A behavioural indicator of particular relevance to robotic milking systems is the time budget of the cows, i.e. how much time they spend in different basic activities. Increased standing time may indicate stress or discomfort, and cows of low social rank spend more time standing, because they have to wait in front of the robot. Also, it is extremely important to determine how behaviour is influenced by numerous milking. The lying behaviour patterns of cow milked in a RMS would be different from those milked in a conventional system, particularly since the distribution of milking events in an RMS occurs over a 24 h period. DeVries *et al*. (2010) noted less synchrony in the behaviour of RMS milked cows, resulting in less daily time spent lying down. Also, some cows tend to be less active after midnight, so robots are often idle during the early hours of the morning.

Usage of an RMS requires cows to be more self-motivated and independent in contrast to cows being milked in a conventional parlour. Therefore, their behaviour and temperament especially is one of the most substantial concerns in the increasing popularity of the RMS. Albright and Arave (1997) describe 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 (Ketelaar-de Lauwere *et al*., 1996; Rushen *et al*., 1999). Cow's temperament consists of multiple traits: fearfulness, activity, sociality (Scott *et al.*, 2014).

Appropriate social behaviour is especially important in a RMS because competition at the entrance occurs. In a study by Bach *et al.* (2009), cows with a higher dominance value spent less time in the waiting area. Ketelaar-de Lauwere (2000) demonstrated that the type of RMS has a marked influence on the cows' subsequent behaviour. Non-milking visits and failed attachments were followed more often by incomplete behavioural cycles. Stefanowska *et al*. (1999a) found that a missed milking negatively influenced cow behaviour, such as less time spent lying and more frequent urinating. Longer post-milking standing durations were associated with cows of higher parity (Norring *et al*., 2012; Deming, 2013).

Social order plays a strong role in determining an individual animal's access to a resource, and in competitive situations (Broucek *et al*., 2011). Low-ranked cows spent more time in the waiting area, while high-ranked cows spent more time in the resting area (Prescott *et al*., 1998; Rushen *et al*., 1999b). The physical restrictions given by the size, use and the design of different parts of the barn have a major impact on the social behaviour of housed cows (Manteca and Deag, 1993). Installing robots not only changes the way the operation runs, but more importantly, it allows each cow to reveal her natural behaviour (DeVries *et al*., 2011).

Some studies found higher levels of restlessness behaviour such as stepping, foot-lifting and kicking in RMS than in a milking parlour. Stepping during milking can be used as an indicator of general discomfort and fear towards humans. A higher frequency of stepping behaviour is observed in anxious and nervous animals. Cows which are managed gently show a shorter flight distance and less stepping behaviour during milking (Phillips and Rind, 2001). Note that cows which experience pain due to teat lesions are more likely to kick during milking. Kicking is also an indicator of discomfort caused by low milk flow and vacuum milking. Defecation, urination and vocalization in RMS are parameters of acute stress and fear in cows. These measures increase when the cows are isolated or introduced in novel surroundings (Munksgaard and Jensen, 1996; Kilgour, 1998; Broucek *et al*., 2003).

Kicking of the cow while inside the RMS can present many problems. 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 (Watters *et al*., 2013). Not just kicking in the RMS could 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.

Robotic milking machines are novel technologies that take over the labour of dairy farming and reduce the need for human-animal interactions. The introduction to a new housing system is being exposed to new human handlers. Cattle show individual variation in their behavioural responses to handling and management systems on farms. These behavioural responses are presumed to reflect underlying temperament traits such as fear or aggression. Handling problems cause higher labour costs, injuries to stockpersons and cattle or even deadly accidents. Therefore, farmers are demanding docile cattle with "good temperament", which enable easy, safe and fast handling (Wechsler and Lea, 2007). Dairy cows were found to keep a longer distance from an aversive than a gentle handler (Munksgaard *et al*., 2005; Rushen *et al*., 2012).

The presence of an aversive handler (sudden and unpredictable movements, shouting and/or slapping) during milking is sufficient to cause the cows to "hold-back" milk due to the suppression of oxytocin secretion. Studies comparing farms with similar environmental conditions and cows with the same genetic background have shown that farms with the highest production are those with stockpersons that speak to and touch their cows more often. The animals are, in turn, less frightened, less reluctant to being driven and more likely to approach the stockperson. Under controlled conditions, just the presence of an aversive handler during milking is sufficient to increase residual milk by 70 % and therefore reduce milk yield (Munksgaard *et al*., 2001; Wechsler and Lea, 2007; Rushen *et al*., 2012).

The behavioural response of cows to a stressful situation increases the risk of injury for the stockman. The expression of fearfulness is the result of interactive processes related to past experiences and the animal's genetic background (Hemsworth *et al*., 1995; Burrow, 1997; Broucek *et al.*, 2004). Cattle show individual variation in their behavioural responses to handling and management systems on farms. However, dairy cows kept in large herds, and especially primiparous cows are more prone to exhibiting behaviour that can compromise both stock person's safety and animal welfare (Sabbioni *et al.*, 2012; Popescu *et al*., 2013).

What to pay attention on

From a technical point of view RMS is proposed perfectly, but requires improvement in terms of the protection and welfare of dairy cows. Cows milked more than twice per day produced more milk (Hart, 2013). However, several cows are milked less than twice a day in RMS and may therefore produce less milk. Robotic herding would improve animal well-being by allowing cows to move into RMS whenever. However, the teats could be sore from mastitis or of being milked too frequently. If the robot can't attach optimally milking speed goes down, stay time in RMS increases and if the cows are not milked properly they might develop mastitis which can be resulted in milk quality problems.

Milking speed is also affected by the cow's temperament; a nervous animal will have an increased level of adrenalin, which can block the oxytocin reflex and interrupt the milk let-down (Falkenberg *et al*., 2013). There is a risk for failure of milking, such as missed attachment of the milking cluster.

Although the benefits reaped from a RMS are extensive, there are a few drawbacks. Milk quality is a critical concern on modern dairy farms, because milk payment systems are based on milk quality and consumers expect a high level of quality and safety from the milk products. Milk quality can be reduced in some cases, welfare and health can be compromised. Although RMS uses the same milking principles as conventional milking, there are major differences. The RMS is in use for 24 hours continuously. Visual control during the milking process is not possible. Cows will visit the RMS more or less voluntarily and this will result in a big variation in the milking frequency from cow to cow. All these aspects may influence the quality of the milk produced (Klungel *et al*., 2000; De Koning, 2010).

A variety of stressors, such social isolation, novel surroundings (especially for heifers) or fear of people present at milking lead to an inhibition of milk ejection. Chronic pain associated with diseases or injuries and any stressful situations occurring during milking are likely to produce a decrease in milk yield. Acute stress during milking reduces milk yield through a central inhibition of oxytocin secretion and peripheral actions of catecholamines. Oxytocin, which is a hormone secreted by the central nervous system into the blood stream, is the main mediator of the milk ejection reflex. The secretion of oxytocin is then of major importance to optimize milk production (Falkenberg *et al*., 2013). Changes in the milking parlour can also affect cow behaviour after relocation (Hillerton *et al*., 2001). Being milked in an unfamiliar environment can cause the inhibition of milk ejection (Macuhova *et al*., 2008).

A lame cow is unwilling to move and will not go to the robot. Udder conformation has improved a lot with modern genetics, but there has been a selection for bulls and cows that transmit close rear teats, which works well in a parlour, but can be difficult to find for the robot (Bijl *et al*., 2007; Weary *et al*., 2009; Tongel and Broucek, 2010). Teat size and adequate teat placement is also important, and good consistency from cow to cow is preferable; if teat sizes vary a lot it can be difficult to choose the right liner (Mihina *et al*., 2012; Caria *et al*., 2014).

With respect to the welfare of the dairy cow, the use of RMS has both advantages and disadvantages. Some recent studies conclude that automatic milking and conventional milking are equally acceptable in terms of welfare of the dairy cow (Pastell *et al*., 2006; Jago and Kerrisk, 2011). Stressed or uncomfortable cow might start kicking in the RMS machine. It prolongs the milking time and number of milkings goes down. Long waiting in the holding area and in the RMS after milking caused stress in animals. This will impact the milk yield, resulting in less efficiency, a decrease in production and lower profitability. Cows may be unwilling to enter a milking parlour voluntarily after negative experiences with inconvenient human contact (Broucek *et al.*, 2008).

According to our results (Broucek *et al*., 2013a), cows of high social rank entered the milking parlour more often without spending time in a queue. In contrary, cows of low social rank had a longer total daily waiting time in front of the RMS. Also, these submissive cows could spend less time in the resting area. The overcrowding develops psychological stress in animals. Increasing of animal density after milking manner change can lead to a decrease in the amount of lying time per day. Every movement of animals and their grouping makes confusion among them. For example, some authors (Bouissou *et al*., 2001; Huzzey *et al*., 2006; Neisen *et al*., 2009) showed that high stocking density at the feeding alley influenced negatively the feeding time and the competition among the cows. Cows ranked lower in the social hierarchy were more often displaced (Galindo and Broom, 2000; Gonzales *et al*., 2003;

DeVries *et al*., 2004). Group housing management and amount of bedding in particular, can have a significant effect on the comfort of cows, as well as free-stall associated lying behaviour (Ketelaar-de Lauwere *et al.*, 1996; Fregonesi and Leaver, 2002; Lendelová and Pogran, 2003; von Keyserlingk and Weary, 2009). Potter and Broom (1987) and Phillips and Rind (2001) highlighted the importance of sufficient space for feeding and resting to allow the herd to adaptation.

The RMS required the distribution of cow behavioural activity throughout the day. The maintenance behaviour patterns of cows could be changed (Adamczyk *et al.*, 2011; Broucek *et al*., 2013b). The synchrony behaviour could be different. Cows do not disturb each other. This would impair their well-being.

Adaptability of cows to robotic milking

The procedures proposed solutions are highly topical. Many dairy buildings are relatively old and cow freedom is restricted. Therefore, a number of farms will currently change the manner of milking on RMS. However, the relocation process has been implicated as one of the major aversions for received cattle (Grandin, 1999; Broucek *et al*., 2013b). The stress associated with removing and arrival at a new facility with milking change can be one of the most stressful situations an animal experiences and can cause a number of physiological and behavioural changes including altered hormones, parameters of energy and protein metabolism, and also changes in milk production (Koolhaas *et al.*, 2010). During relocation cattle are subjected to noise, strange surroundings, odours and companions, overcrowding or sometimes isolation, hot or cold conditions and a change of feed (Grandin, 2003). All these factors contribute to stress and potential performance losses. Replacing conventional twice-a-day milking managed by people with a system that supposedly allows cows the freedom to be milked automatically whenever they choose, it is claimed that robotic milking has health and welfare benefits for cows, increases productivity, and has lifestyle advantages for dairy farmers (Holloway, 2013).

Cows have two motivations to enter the robot: access to concentrate and emptying of the udder. In standard conditions, concentrate is provided in predetermined quantities to the cow while she is being milked. When feed was provided, cows were faster to exit the pre-milking yard, they have a shorter time spent waiting (Scott *et al*., 2014). 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. With free access, cows do not have to be milked in order to enter the feeding area. This system allows unlimited access to forage. Cows can join the milking robot every time and therefore the interval between milkings is not fixed. The frequency, with which cows choose to be milked, has been reported to range from 1.2 to 5 times a day (Pastell *et al*., 2006).

The cow's motivation to enter the milking stall is the major difference between RMS and conventional milking systems. In conventional milking routines, the cows are driven to the milking parlour two to three times daily. In RMS, the cows enter the milking stall voluntarily and are milked throughout the day without human intervention. It has been demonstrated that cattle can be trained to approach a feed source after hearing an audio signal (Arnold *et al*., 2008). However, some 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 RMS. More than 15 % of the herd needs to be forcing to visit. Therefore, training cows to use a RMS is an important process, as this method of milking depends on cows voluntarily using the RMS. Jago and Kerrisk (2011) found that voluntary milkings were achieved by 92 % of heifers and 81 % of cows within 6 days following their first assisted milking. Heifers achieved their first voluntary milking quicker than cows. Pre-calving training improved aspects of the behaviour required for successful adaptation to RMS but had little impact on time to achieve a voluntary milking. Generally, cows must learn to manipulate automatic feeders, water bowls and to enter the milking unit. Therefore, cattle can be trained to perform different kinds of tasks (Kilgour *et al*., 1991; Veissier *et al*., 1993). Operant conditioning techniques have been used on cattle to measure feed preferences (Arave, 1996), handling preferences (Pajor *et al*., 2000) and behavioural needs (Broucek *et al*., 2002; Broucek *et al*., 2003; Wredle *et al*., 2006).

To ensure motivation and performance it is important to develop a consistent training routine for heifers and cows. Training cows to use a RMS is an important process as this method of milking depends on cows voluntarily using the RMS. According to our recent results, we assume that primiparous cows adapted to automatic milking quicker than older cows (Broucek *et al*., 2013a).

We assume that experienced cows will enter the RMS voluntarily without any intervention by the staff or their adaptation period after a transient period of parlour milking will be short. However, main attention should be focused on the behaviour of inexperienced cows. Our preliminary results are alarming, inexperienced cows need an intensive help for adaptation to the RMS in order to minimize production loss. So, the adequate adaptation is crucial for successful milk production in RMS. Time efficiency and time usage in RMS are key aspects in robotic milking, and a stressed or uncomfortable cow might start kicking in the machine, which will result in longer attachment time.

Heart rate variability is an alternative measure that has been used recently for the evaluation of stress responses in dairy cows (Lay *et al*., 1992; Kovács *et al*., 2013). Weiss *et al*. (2004) found that most cows adapted to the RMS within few days, but there was wide individual variation of heart rate among cows. The adaptability seemed to be related to the individual sensitivity of their adrenal cortex (Hagen *et al*., 2005; Gygax *et al*., 2007).

Cows' performance in housing systems with RMS can depend on their temperamental traits. Avoidance of the RMS can be related to a fear but also to unfavourable temperament. Cows in RMS need to have the same functional traits as cows in other milking systems, but in addition, they also need an appropriate temperament; calm but driven. Environmental conditions which elicit physiological coping responses in animals, it causes deterioration of well-being and slow adaptation of cattle (Albright and Arave, 1997). The first stage is acclimatization to an RMS, which takes a few or more days in most circumstances. However, adapting to a new system may be more difficult for some cows than others (Wenzel *et al*., 2003; Deming *et al*., 2013).

It is necessary to develop methods and procedures for easier adaptation of cows to RMS. More authors reported how habituation was used to encourage dairy cows to enter the automatic milking system (Hagen *et al*., 2005; Scott *et al*., 2014). The problem may be the noise of the robot. Arnold et al. (2008) examined the effect of noise on choice behaviour of dairy heifers in a maze. Animals took longer to enter the noise maze arm compared to the quiet arm during training trials. From studies in calves and heifers in the maze learning it is known that differences in response between animals may originate from rearing conditions (Broucek *et al*., 2002). Broucek *et al.* (2007) indicated that heifers are reluctant to change their initial choice. It is possible that the willingness or reluctance also can be seen in cows. Reaction may be due to previous experience in some food, which was previously received as a reward, but it was not used.

Wicks *et al.* (2004) investigated the effect of habituating heifers to the milking parlour environment prior to calving on subsequent lactation performance. Habituated heifers yielded at 1.3 kg per day more milk than the control group of heifers over the first 100 days of lactation. Results of Sutherland and Huddart (2012) suggest that trained heifers may have experienced less distress during the first week of lactation, but the effect of training on the behavioural and physiological responses to milking appeared to be influenced by heifer temperament. Svennersten-Sjaunja and Pettersson (2008) found that missed milking negatively influenced cow behaviour, such as less time spent lying and more frequent urinating. The heifers that were allowed to get familiar with the milking parlour before calving had lower heart rates on the first day of lactation than the heifers that had not been familiarized with the new surroundings. According to Schwalm *et al.* (2012) this difference was no longer apparent on day nine of lactation. The heifers habituated quickly to the milking situation including the noise in the milking parlour.

CONCLUSIONS

Farmers, after the introduction of robots, have various problems (substantial deterioration in the quality of milk, non-standard behaviour of dairy cows and many other problems). Therefore, the applied ethological research of robotic milking is highly required.

Generally, the benefits of automation for dairy farm can be seen in improved profitability, animal health, milk quality and farmer lifestyle. A robotic milking is therefore highly topical task. Manual labour is partly replaced by management and control, so the presence of the operator at regular milking times is no longer required. However, the effects of the changeover from conventional parlour to an automatic milking system (RMS) on performance, behaviour and physiological parameters in dairy cows with or without previous experience in RMS milking should be investigated.

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