UNIVERSITY OF CALGARY

The Adoption of Automatic Milking Systems on Canadian Dairy Farms: Changes in Cow

Health, Management and Animal Welfare

by

Christina Tse

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN VETERINARY MEDICAL SCIENCES

CALGARY, ALBERTA

JULY, 2016

Abstract

Producers with automatic milking systems (AMS) were surveyed to explore the impacts of AMS on their cows and to determine how producers experienced the transition. Producers perceived their transitions to AMS as successful and would recommend it. Cleaning and feeding practices stayed the same. Farms increased herd size, but decreased the number of employees and time devoted to milking labour management. There was little perceived effect on milk quality and cow health. Producers changed health management practices, but majority found health detection easier. Only 20% of producers referred to the Dairy Code of Practice when making plans to adopt AMS. Participation in Dairy Herd Improvement programs decreased. It took on average 7 d to train a cow/heifer to use AMS and 30 d for an entire herd to adapt. Despite some challenges, producers reported that AMS improved profitability, quality of their lives and their cows' lives, and had met expectations.

Acknowledgements

Dr. Elsa Vasseur at McGill University). This project would have been immensely more gruelling without all of your help.

Thank you to Guilherme Bond and Larissa Condas for your constant encouragement and for the countless coffee breaks. I am incredibly grateful for your friendship, guidance and free Portuguese lessons. You two played an integral part in keeping me (mostly) sane. Writing this thesis simply would not have been possible if I had lost my marbles in the process.

Mom, Dad, Lurdes and Arun, thanks for being the amazing, supportive family that you are. And lastly, thank you to my husband, Brennen, for getting me through this. You cheered me on when I felt like I could take on the world and you gently put me back together when I felt beat up. Words cannot explain my appreciation for you, your undying patience, and you always being on my side.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AMS   Automatic milking systems

CMS   Conventional milking systems

BTSCC   Bulk tank somatic cell count

NEB   Negative energy balance

DHI   Dairy Herd Improvement

DCOP   Dairy Code of Practice

IQR   Interquartile range

Chapter One: **Review of Literature**

1.1 What are Automatic Milking Systems and why are Farms Using Them?

Automatic milking systems (**AMS**) are also referred to as robotic milking and voluntary milking systems. In conventional milking systems (**CMS**) of free-stall dairy farms, cows are milked in a milking parlour at set times, 2 to 3 times/d, which requires human labour. In AMS, cows are not limited to 2 or 3 milkings/d as they are permitted to voluntarily visit a robotic unit multiple times/d to be milked without human labour. AMS was first introduced to commercial dairy systems in 1992 (de Koning, 2010). Increasing labour costs and the need for improved labour efficacy led to the adoption of AMS (Borderas et al., 2008). It is suggested that AMS is one of the few strategies that allows small to medium sized family farms to remain economically competitive (Reinemann and Smith, 2000). However, AMS producers have given social reasons (e.g., having more flexibility, improving health and social life) as the most important reasons for adopting this technology (Mathijs, 2004), which suggests that the transition to AMS has not only been economically motivated.

For AMS to work, the robotic unit must provide highly palatable, concentrated feed during milking, as a full udder is not enough to motivate a cow to be milked (Prescott et al., 1998). After an initial period of training or adapting, the cows associate the AMS unit with being provided concentrated feed (Rodenburg, 2011). As the cow enters the unit, her identification tag is registered with the control system. The teats are prepared (cleaned) for teat cup attachment. A hydraulic arm then attaches the teat cups to the cow's teats using a teat position sensor and milking occurs. Milking is often followed by teat spraying of an approved disinfectant. The cow may be denied milking if she was milked too recently and, depending on the cow traffic system

either may not be permitted entry to the unit or she must exit the robot without being milked or fed (Hulsen & Rodenburg, 2008).

AMS is designed to work with different cow traffic systems. In free-flow (or free-cow) traffic systems, cows may eat, visit the milking unit or rest in the free-stalls, as they desire (Lely, 2010). In directed- (or guided-) traffic systems, cows are directed by pre-selection gates to either undergo milking first or, if they do not have milking permission, are diverted to the feeding or lying area (DeLaval International AB, 2008). Milking permission in any traffic system is gained after a specified period of time has passed since her last milking. Directed-traffic systems use herd management software to determine if a cow gains access to the robot. With milk-first directed-traffic systems, the selection gates are placed in front of the AMS; cows are either directed to the milking unit or the feeding area depending on if she has permission to be milked. From the feeding area, the cow has free access (via one-way gates) to the lying area. A cow's motivation to feed ensures that she visits the milking unit in this traffic system (Prescott et al., 1998; Lind et al., 2000). With feed-first directed-traffic systems, access to the lying area is controlled instead of the feeding area. In other words, cows have free access (via one-way gates) to the feeding area from the lying area. The cows' motivation to lie down after feeding ensures that the cows visit the milking unit (Markey, 2013).

Robotic milking allows for precision dairying. Precision dairying involves the use of a variety of technology to improve farm management and performance by managing individual cows within a herd (Yule and Eastwood, 2011). The AMS collects a vast amount of information on the cow, her milk, and overall milking activity at every milking. Depending on the brand and model of the AMS, milk measurements (such as quantity, quality and flow rate) may be provided per quarter of the udder or simply per cow as a whole. This quantity of information would be

unobtainable on-farms in a conventional milking system. Information collected may include: number of visits to the robot per day; duration since last milking on a per cow basis; number of refusals that occur per day (refusals occur if the cow returns to the unit too soon); number of attachment failures (i.e., when the robotic arm fails to attach teat cups to the cow's teats); milk yield per cow; conductivity, temperature, and colour of milk; clots in the milk; milking time and speed; and somatic cell count, milk fat and milk protein content (Hulsen & Rodenburg, 2008; DeLaval Canada, 2014). When certain values of milk quality or other cow health-related measurements are out of range, the system sends a notification (also called an alarm) to the producer's cellular phone so that the issue can be addressed in a timely manner. Alarms are also produced if a cow has not come in to get milked in a certain amount of time, and if there are any maintenance issues with the robot (Lely, 2010; DeLaval Canada, 2014).

Producers that have adopted AMS have reported an increase in milking frequency and milk yield, improved cow comfort, and a more flexible lifestyle (de Koning, 2010). Other demonstrated benefits to AMS include needing less labour (Hansen, 2015), improved cow health, and more interesting activities for the producer (Woodford et al., 2015). However there are compromises: an AMS has higher capital costs (Wade et al., 2004), requires producers to be on-call, and changes management to be more data-based (Butler et al., 2012). On average 5 to 10% of AMS farmers switch back to CMS (de Koning and Rodenburg, 2004). It is unknown if the rate of return to CMS has remained constant in the past decade.

1.2 Changes in Farm Management and Housing

The management of dairy farms with AMS is very different from CMS. On farms with AMS, not only is it necessary for the producer to be on-call for alarms, but their role on farm

also changes from hands on interactions with the herd to more data-based methods for identifying health and welfare issues (de Koning, 2010; Butler et al., 2012). Learning to understand and use the information collected by the robot may be particularly challenging (Bewley and Russell, 2010; Butler et al., 2012). The vast amount of data provided by this technology could be misinterpreted, misused, or even ignored.

With AMS, management is more sensitive to the criteria for a "good" dairy cow, as not all cows are suitable for robotic milking (see review by Jacobs and Siegford, 2012a). The wrong conformation may result in failed cluster attachments and subsequently, failed milkings. In terms of temperament, cows that kick off the milking cluster can also cause incomplete/failed milkings, and unmotivated cows become repeated fetch cows. Furthermore, producers should be prepared that some cows may not adapt well to the robotic unit due to poor legs and feet (Jacobs and Siegford, 2012a). Culling rate may increase, or the reasons for culling may change, as a result of these restrictions (Meskens et al., 2001). It was suggested in a review that dairy herd managers are willing to increase their rate of replacement by 5% to use AMS (Armstrong and Daugherty, 1997). Producers in Ontario, Canada, culled between 0 to 3% more cows with AMS due to close teat placements, unusual udder conformation, and involuntarily attended milkings when otherwise physically and behaviourally normal (Rodenburg, 2002).

Modifying an existing building or building a new barn is necessary for the installation of a robotic milking unit. It is more common for producers to build new facilities for the AMS than to retrofit an existing barn (Bentley et al., 2013; Woodford et al., 2015). Stocking density (cows/stall) should be minimized since lower stocking density has been associated with increased milking frequency in AMS farms (Deming et al., 2013). Furthermore, Rousing et al. (2007) determined that veterinarians, AMS researchers and dealers, recognize stocking density

as an important animal welfare indicator on AMS farms. Details of ideal stocking density on AMS farms were not provided in that study.

Barn design should be taken into account when modifying or building farm. AMS dealers recommend a ratio of 50 to 60 cows/robot (DeLaval International AB, 2008; Hulsen and Rodenburg, 2008). A recent AMS study conducted in North America showed that having 2 robots/pen with 120 cows was associated with greater milk production/robot/d than 1 robot/pen with 60 cows (Tremblay et al., 2016). The study also concluded that free-flow traffic systems had greater milk production than directed-traffic systems. Although there tends to be less crowding in the milking area with directed-traffic systems since only eligible cows have access (de Koning, 2010). Design criteria for an ideal AMS barn have been summarized by Rodenburg et al. (2010).

Space allocation for the feed bunk also warrants consideration when modifying or building a new barn. Less bunk space may be necessary for cows in AMS because of a lower, but more consistent, percentage of cows eating at the feed bunk at one time (Wagner-Storch and Palmer, 2003). However, greater milk yield has been achieved by ensuring that cows have ample feed bunk space with feed readily available to them (Deming et al., 2013). There has been no documentation showing whether new dairies with AMS have purposefully increased, decreased or maintained feed bunk space as part of their building plans. Additionally, there are no recommendations from AMS companies as to how feed bunk space should be managed differently from CMS.

When switching to AMS, it is necessary to re-balance the cows' nutrition as production level may change and because high concentrate feed is now delivered in the robotic unit. A proper diet is important in avoiding a negative energy balance, which may occur in high

5

producing cows in AMS (Widegren, 2014). Typically, the cost of feed becomes a greater expense after adopting AMS because more feed must be consumed to compensate the increase in milk production (Rotz et al., 2003). One study showed no difference in feed intake of mixed ration and concentrates with AMS, however there was also no difference in milk yield between their AMS and CMS cows (Wirtz et al., 2004).

1.3 Changes in Milking Labour Management, Milk Production and Quality

1.3.1 Milking Labour Management

In this thesis, milking labour management in AMS refers to fetching cows for milking, cleaning and preparing the AMS unit, and addressing maintenance issues. For CMS milking labour management refers to moving cows to the holding pen, preparing, milking in and cleaning the parlour.

With AMS, teat cleaning, milking, and separation of abnormal milk are integrated into the robotic unit, which reduces labour. Labour savings with AMS, which has been reported to range from 18 to 38% (Sonck, 1995; Mathijs, 2004; Bijl et al., 2007), varies depending on the management capabilities of producers (van't Land et al., 2000). Labour savings with this technology has not been looked at in detail in Canada.

The average proportion of cows fetched per day ranges from 4 to 25% of a herd (Rodenburg and House, 2007). Munskgaard et al. (2011) documented an 83% occupation rate/d in both free-flow and directed-traffic AMS. A recent study, which looked at data from 635 North American Lely AMS farms, calculated an average of 5.5 failed or incomplete milkings/robot/d (Tremblay et al., 2016).

1.3.2 Milk Production

Milk production increases with the transition from CMS to AMS (Wagner-Storch and Palmer, 2003; Hansen, 2015; Woodford et al., 2015). The average increase in milk yield ranges from 2 to 25% (Reinemann and Davis, 2002; de Koning and Rodenburg, 2004; Bernier-Dodier et al., 2010). Tremblay et al. (2016) documented an average milk yield of 32 kg/cow/d in AMS dairy farms. The positive relationship between milk yield and milking frequency may be a result of the occurrence of more frequent milkings using AMS (Erdman and Varner, 1995; Melin et al., 2005). Physiologically, increasing milking frequency removes a polypeptide called feedback inhibitor of lactation at a higher frequency, which results in an increase in milk yield (Knight and Dewhurst, 1994). However, not all researchers agree that milking frequency and milk yield are related (Migliorati et al., 2005; Spolders et al., 2004).

AMS studies have reported that cows are milked on average more than 2 times/d. Although CMS may milk cows 2 or 3 times/d, the important component in AMS is the range of milking frequencies and the flexibility in which milkings may occur. For example, Svennersten-Sjaunja et al. (2000) determined that AMS cows milked on average 2.38 times/d, while Prescott et al. (1998) reported that high producers milked on average 3.3 times/d, while low producers milked 2.1 times/d in AMS.

1.3.3 Milk Quality

AMS milk quality is influenced by cleanliness of the teats, udder health, the milking process (transport, cooling), and cleanliness of the milking equipment (Elmoslemany et al., 2009). Milk quality has been reported to be slightly, but significantly, lower in AMS farms. Freezing point, free fatty acids, and total bacterial count are higher after transition to AMS

(Klungel et al., 2000; Meskens et al., 2001; van der Vorst et al., 2002), but the effect of AMS on bulk tank SCC (**BTSCC**) has been inconsistent. Studies have shown BTSCC to be higher (Kruip et al., 2002; Rasmussen et al., 2002; de Koning et al., 2003), lower (Shoshani and Chaffer, 2002; Bentley et al., 2013; Tousova et al., 2014), or no different (Zecconi et al., 2003; Salovuo et al., 2005; Helgren and Reinemann, 2006) from CMS. AMS have improved in the last decade (Tremblay et al., in press), so it is possible that the studies reporting an increase in BTSCC are less applicable.

Similar to BTSCC, the effects of AMS on milk fat and milk protein content have also varied. Tousova et al. (2014) documented an increase in milk fat and protein content with the use of AMS. Shoshani and Chaffer (2002) determined that cows milked in AMS had lower fat content and no difference in milk protein. Two studies showed that milk fat and protein did not change after transitioning to AMS (Klungel et al., 2000; Svennersten-Sjaunja et al., 2000).

The variation in BTSCC, milk fat and protein, findings may be a result of differences in experimental design and differences in sampling methods in AMS and CMS. For example, comparing the effects of AMS and CMS on milk quality using the same herd would elicit different results if one was to compare the same variables using different herds for each system (Berglund et al., 2002). A recent AMS study showed a positive correlation between variation in milking interval and SCC, suggesting that variation in milking intervals should be addressed in the research designs of and during analysis for AMS studies looking at SCC (Mollenhorst et al., 2011).

1.4 Changes in Cow Health

1.4.1 Udder Health

Udder health and prevalence of mastitis are important aspects of dairying, as better udder health has been associated with higher milk production (Neijenhuis et al., 2010). Teat cleaning and automatic detection of mastitis are challenges for AMS (see review by Hovinen and Pyörälä, 2011). Incidence of mastitis has been documented to be the same in cows milked in AMS and CMS (Wirtz et al., 2004). However, a Finnish study found an increase in frequency of mastitis treatments on AMS farms in multiparous cows and a decrease for first-parity cows (Hovinen et al., 2009). To date there is no literature documenting how the incidence of clinical mastitis changes in relation to how long a herd has been using AMS.

Milk leakage, or the dripping of milk from the teats between milkings, occurs more often and to a greater proportion of a herd in AMS compared to CMS (Persson Waller et al., 2003). Milk leakage may occur after the failure of cluster attachment because the cow subsequently leaves the robot without being milked, and the visit is marked as a failed milking (Stefanowska et al., 2000). Milk leakage due to failure of cluster attachment has shown to increase the risk of mastitis on AMS farms (Stefanowska et al., 2000). As well, a potential side effect of increased milking frequency using AMS is the increased risk of udder infection as teat ducts are open more frequently, which may increase the chance for bacteria to enter (Waage et al., 2001). This has negated an early belief that the rate of mastitis may decrease in AMS as a result of teat ducts being more efficiently stripped of pathogens with more frequent milkings (Hillerton and Winter, 1992). Providing fresh feed throughout the day may entice cows to feed after milking rather than lie down, which would benefit udder health (DeVries et al., 2010).

Total bacterial count has been reported to increase after transitioning to AMS (Klungel et al., 2000; Rasmussen et al., 2002; de Koning et al., 2003). However, these studies are more than 10 yrs old. AMS technology and management of these systems have improved over the years (Tremblay et al., in press). New research is needed to confirm if changes in the technology are resulting in improvements in variables such as total bacterial count.

AMS does not have a negative effect on teat skin condition. A study that assessed quarter milk samples and teat measurements concluded that although teat apex and skin conditions decreased slightly with the accumulated number of milkings, AMS did not have a negative impact on teat tissue conditions (Zecconi et al., 2003). Similar results by Berglund et al. (2002) and De Vliegher et al. (2003) suggest that teat end and skin condition remain consistent, and may even improve, during the transition from CMS to AMS.

1.4.2 Lameness

Lameness is a welfare issue for cows because being lame is painful (von Keyserlingk et al., 2009; Solano et al., 2015). Lameness is a problem that is affected by many factors, such as nutrition, cleanliness of barn, trauma, resting behaviour, preventative and corrective treatment, and a number of other individual cow factors (Greenough et al., 1981). Westin et al. (2016) determined farm-level risk factors for lameness on AMS farms and concluded that narrow stalls (relative to cow size and parity), a narrow feed alley, and inadequate lunge space in stalls were associated with higher odds of being lame.

Cows with feet and leg pain will visit the robotic milker less frequently than those that are not lame, or are less likely to voluntarily visit the AMS unit at all (Bach et al., 2007; Borderas et al., 2008; Miguel-Pacheco et al., 2014). Borderas et al., (2008) showed that milk

yield is negatively affected when lameness causes a decrease in AMS visits. Lameness increases the number of alarms for fetching cows, which may decrease producer satisfaction with AMS. However, a recent study observed a lower prevalence of lameness in AMS herds than what was previously documented in Canadian dairies with CMS (Westin et al., 2016).

1.4.3 Reproduction

It has been hypothesized that AMS increases the risk of negative energy balance (**NEB**) and thus would negatively impact cow fertility, the ability to conceive a calf (Kruip et al., 2002). A NEB may result from a disproportional amount of feed intake with respect to the higher milking frequencies and milk yield in AMS (Kruip et al., 2002). A NEB negatively impacts glucose and insulin levels, which are important factors in fertility (Kruip et al., 2000). However, several experimental studies (Devir et al., 1993; Kruip et al., 2000; 2002), and one survey study (Bentley et al., 2013), have reported no negative effects on conception rate with AMS.

1.5 Cow Training

Training is an important aspect of transitioning to AMS. The act of training involves exposing the cow or heifer to the sounds and mechanical movements of the AMS prior to first milking with the robot. Doing so has made transitioning cows to AMS easier (Jago and Kerrisk, 2011). Introducing heifers to the AMS prior to calving had a positive impact on milking intervals, frequency of feeding, and milk production after calving (Widegren, 2014). Studies suggest it takes 7 to 8 d for cows to adapt to AMS (Spolders et al., 2004; Jacobs and Siegford, 2012b), although on average 3 to 5% of dairy herds do not adapt to this technology (Armstrong and Daughtery, 1997).

AMS companies, like Lely and DeLaval, recommend following a cow-training program to help with the transition to and use of AMS. However, these programs are not standardized, often differing in method, duration and specificity. DeLaval recommends the following 2 to 3-wk training program that should start a week or two before start-up: have cows visit the robot 1 to 2 times/d for the first week (without milking, but providing high concentrate feed), then 4 to 6 times/d for the second week (DeLaval International AB, 2008). Lely's recommended method for training is to entice cows into the robot 3 times/d for the first 3 d. This recommendation comes with an expectation that 75% of the cows will go to the robots on their own by the end of the third day. Lely emphasizes small training groups of 25 to 30 cows and having at least 2 stockpersons/robot the first few days (Hulsen and Rodenburg, 2008). Little is known about whether or not producers invest time in cow training or what methods they use.

1.6 Animal Welfare

In this thesis, the term 'animal welfare' encompasses 3 objectives as identified by Fraser (2009): to ensure good physiological health and functioning of animals, to limit unpleasant affective states such as pain, fear and distress, and to allow animals to grow and live in a way that is natural for the animal (i.e., to allow expression of innate behaviours). Included in this definition of animal welfare is the core concept of "The Five Freedoms" (Webster, 2005): animals must have a freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury or disease, freedom to express normal behaviour, and freedom from fear and distress. A recent paper by Mellor (2016) pushes the concept of animal welfare to acknowledge that it is a subjective state experienced by the animal and that in order to achieve good animal welfare we must also help the animal have a life worth living.

It has been suggested that AMS improves cow welfare. Cows are given more autonomy and control over their daily time budget with AMS since they determine when milking occurs (Driessen and Heutinck, 2015; Lind et al., 2000). This technology also has the potential to improve welfare by detecting health issues more efficiently and effectively than possible with human observations and allows for earlier treatment (see review by Barkema et al., 2015). However, the novelty of the robotic unit and learning to be milked in isolation from the herd may cause acute stress in the herd animals (Rushen et al., 2001). Rousing et al. (2007) assessed 38 welfare indicators for AMS and determined that housing design, stocking rate, cleaning and feeding routines, lameness and udder health, human-animal relationship, social behaviour, and behaviour during milking, were the most important indicators of welfare according to researchers, production advisors and veterinarians.

1.7 Quality of Producers' Lives with AMS

AMS has had a positive effect on the quality of producers' lives: AMS provided producers with more flexible working hours, which improved producers' family and social life (Rasmussen et al., 2002), as well as increased job satisfaction (Woodford et al., 2014; Hansen, 2015). It has also been generally accepted that the health of producers improves with the reduced physical workload (see review by Meskens et al., 2001). In an Australian study that investigated the impacts of AMS on labour and lifestyle of farmers, all farm audits showed that AMS had improved quality of life and that all participants felt their expectations around AMS were met (Molfino et al., 2014). Bergman and Rabinowicz (2013) found that Swedish AMS producers would recommend transitioning to this new technology to others.

However, there are also challenges with using AMS. Being on-call and feeling overwhelmed by the amount of information the AMS produced were reported challenges that producers have experienced (e.g., Hansen, 2015). Physical contact with cows plays a big role in job satisfaction for some producers (Meskens et al., 2001), and among Swedish producers, having reduced contact with cows was an important reason for not installing this technology (Bergman and Rabinowicz, 2013). Challenges experienced during the transition to AMS have not been documented in detail in Canada.

1.8 Dairy Herd Improvement Programs

Dairy herd improvement (**DHI**) programs collect herd data and milk samples from participating farms, analyse the data and samples, and consolidate information for national evaluations of dairy cattle and milk quality, and for producers to use as a tool for improving herd management and milk quality (Valacta, 2015; CanWestDHI, 2016). There has been concern about reduced participation in DHI programs with AMS becoming more popular, and since AMS produce a large amount of on-farm data that were not available to producers with CMS (Ontario Ministry of Agriculture, Food and Rural Affairs, 2010; Barkema et al., 2015). The program's effectiveness for national evaluations depends on producer participation because enrolment is voluntary. To date, there has been no published documentation of change in the use of DHI programs with the transition to AMS.

1.9 Dairy Code of Practice

The Dairy Code of Practice (**DCOP**) was developed by The National Farm Animal Care Council in collaboration with Dairy Farmers of Canada, with the purpose of considering current

14

dairy management practices and identifying welfare hazards and methods to assure animal welfare. The DCOP is science-informed and includes requirements (as seen as industry imposed expectations, or regulatory requirements) and recommendations for best practices associated with: accommodation, housing and handling facilities, feed and water, health and welfare management, husbandry practices (breeding, dehorning, branding, castration, etc.), transportation, and euthanasia (National Farm Animal Care Council, 2009). Currently, the DCOP addresses dairy farming in terms that are often neither specific to AMS nor CMS. A revision to the DCOP that incorporates the differences in dairying with AMS is essential, as this technology is growing in popularity. In addition, the usage of and compliance to the DCOP on AMS farms has not been documented.

1.10 Project Rationale and Objectives

Although Europe has the highest concentration of AMS dairy farms, this technology is becoming increasingly common in Canada (Barkema et al., 2015). The proportion of dairy farms in Canada that use AMS has grown from 5.6% in 2014 to 6.8% in 2015 (Canadian Dairy Information Centre, 2016). Despite this growing popularity, there is little documentation of how AMS has impacted Canadian farms as a whole (inclusive of cow health, milk parameters, management, housing, and impacts on dairy producers). To facilitate transitioning to AMS there is a need to benchmark transitioning results so producers have realistic expectations, and to identify challenges and solutions associated with transitioning to AMS. The overall aim of the project was to conduct a national survey to explore how Canadian dairy producers transitioned to AMS.

Although results of AMS surveys have been published (e.g., Helgren and Reinemann, 2006; Rodenburg and House, 2007; Rousing et al., 2007; Molfino et al., 2014; Moyes et al., 2014; Tousova et al., 2014), many are non-Canadian studies that focus on a very specific aspect of dairy farming. The Canadian dairy industry differs from that of the United States and European Union in average herd size and milk price (Table 1), and animal welfare standards (Barkema et al., 2015), suggesting that AMS studies conducted abroad may not always reflect the Canadian dairy industry.

The objectives of this study were to document the impacts of transitioning to AMS on producer perceptions of change in important aspects of Canadian dairy farming and to determine how producers experience the transition.

1.11 Research Questions

This study aims to answer the following research questions:

1. What are the impacts of AMS on producer perceptions of change in milking labour management, milk production, milk quality, housing, farm management, cow health, and participation in DHI programs?

2. Are producers training cows/heifers to use the AMS? What does training entail?

3. What challenges do producers experience during the transition and what were the solutions?

4. How has the quality of producers' lives changed as a result of the transition?

5. What is the role of the DCOP on AMS farms? With reference to a subset of requirements in the DCOP, are AMS farms compliant to the codes?

Table 1.1: A comparison of the Canadian, American and European dairy industry

Item	Canada	United States	European Union
Year of Data (unless stated otherwise)	2014	2013	2012
Total Dairy Farms	8,738[1]	49,331 (2012)[3]	508,611 (2009)[6]
Total AMS Farms	493[1]	(no reliable source)	(no reliable source)
Total Dairy Cows (x 1,000)	959[1]	9,224[4]	23,012[6]
Average Herd Size (Adult Cows)	79[1]	173 (2011)[3]	34 (2009)[6]
Supply Management?	Yes[1]	No[3]	Recently abolished[6]
Average Milk Price (CAD)	$0.81/L (2013)[2]	$0.44/L[5]	$0.42/L[6]
Total Annual Production (million lbs)	17,729.4[1]	91,271[5]	71,561[6]
Imports (million lbs, fluid milk and cream only)	124.9[1]	3,721[5]	2,646[6]
Exports (million lbs, fluid milk and cream only)	9.4[1]	12,353[5]	38,147[6]

[1](Canadian Dairy Information Centre, 2015), [2](Alberta Milk, 2014), [3](USDA-NASS, 2013a), [4](USDA-NASS, 2013b), [5](USDA-ERS, 2015), [6](European Dairy Association, 2015)

Chapter Two: **Impact of Transitioning to Automatic Milking Systems on Producers'**
Perceptions of Farm Management and Cow Health in the Canadian Dairy Industry

2.1 Abstract

Automatic milking systems (AMS), or milking robots, are becoming increasingly common, but there is little documentation of how AMS have impacted farms as a whole and what challenges and benefits producers are experiencing during their transition to AMS. The objective of this national survey was to document the impact of transitioning to AMS on producer perceptions of change in housing, farm management, and cow health. In total, 217 AMS producers were surveyed from 8 Canadian provinces. Median time since transition for respondents was 30 mo. The mean number of lactating cows/robot was 51 cows, with a median of 2 AMS units/farm. Fifty-five percent of producers built a new barn to accommodate the AMS. Changing housing systems was necessary for 47% of producers, not necessary for 50%, and not applicable to 3% (as the AMS farm was their first farm). Cleaning and feeding practices remained the same. Overall, farms increased herd size from a median of 77 to 85 lactating cows with the transition to AMS. After the transition to AMS, 66% of producers changed their health management practices. On average, producers reported no change in rate of lameness and clinical mastitis. Conception rate was reported to have increased for 63% of producers. Culling rate was perceived to have stayed the same for 59% of producers. Overall, producers perceived their transitions to AMS as successful. Findings from this project provide a benchmark of the impacts of AMS on important aspects of Canadian dairy farming, as well as provide producers, AMS manufacturers, veterinarians and dairy advisors with more detailed knowledge on what to expect when transitioning to AMS.

2.2 Introduction

When functioning optimally, an automatic milking system (**AMS**) permits cows to voluntarily visit a robotic milking unit multiple times/d to be milked without requiring human labour. Demonstrated benefits of AMS include increased milk production, improved cow comfort, a more flexible lifestyle for producers (de Koning, 2010), less labour for milking (Hansen, 2015) and improved cow health and more interesting/less routine activities for the producer (Woodford et al., 2015). However, an AMS has higher capital costs (Wade et al., 2004), requires producers to be on-call, and changes management to be more data-based (Butler et al., 2012). Profitability or labour savings with AMS varies depending on the management capabilities of producers (van't Land et al., 2000).

Although Europe has the highest concentration of AMS dairy farms, this technology is becoming increasingly common in Canada (Barkema et al., 2015). The proportion of dairy farms in Canada that use AMS has grown from 5.6% in 2014 to 6.8% in 2015 (Canadian Dairy Information Centre, 2016). Despite this growing popularity, there is little documentation of how AMS has impacted North American farms as a whole (inclusive of cow health, milk parameters, management, housing, and dairy producers).

AMS survey studies have been published (e.g., Helgren and Reinemann, 2006; Rodenburg and House, 2007; Rousing et al., 2007; Molfino et al., 2014; Moyes et al., 2014; Tousova et al. 2014). However, many of these are non-Canadian studies that focus on a very specific aspect of dairy farming. The Canadian dairy industry is different from that of the United States and European Union in average herd size, milk price, and animal welfare standards (Barkema et al., 2015), suggesting that AMS studies conducted abroad may not necessarily be reflective of the Canadian dairy industry. Furthermore, few published AMS studies focus on

producers' perceptions of change with the transition to AMS and comprehensively describe the effects of adopting AMS on farms.

The objective of this study was to determine how producers perceive the transition to AMS in terms of resulting changes in housing, farm management, and cow health. Other topics addressed in the survey, as described below, will be reported in additional publications.

2.3 Materials and Methods

This survey study received institutional human ethics certification prior to contacting participants (University of Calgary, certification no. REB14-0149_MOD1).

2.3.1 Farm Selection and Data Collection

Contact information for AMS producers was acquired through Alberta Milk (Edmonton, AB, Canada) and Dairy Farmers of Manitoba (Winnipeg, MB, Canada), which are provincial milk boards, and Lely Canada (Woodstock, ON, Canada) and DeLaval Canada (Peterborough, ON, Canada). All 530 Canadian AMS producers of which we obtained contact information were contacted and data were collected on those willing to participate. AMS farms participating in the study were from British Columbia (**BC**; n = 8), Alberta (**AB**; n = 43), Saskatchewan (**SK**; n = 7), Manitoba (**MB**; n = 12), Ontario (**ON**; n = 73), Quebec (**QC**; n = 66), New Brunswick, and Nova Scotia (Table 1). The latter 2 provinces were grouped together due to the smaller sample size per province, and are referred to as the 'Maritimes' (n = 7). AMS farms in Prince Edward Island and Newfoundland were not surveyed because AMS producers from these provinces could not be reached. The participating farms were surveyed by telephone, email, and in person from May 2014 to the end of June 2015. Consent was received before surveys were conducted.

Respondents were given the option to stop the survey at any point, in which case those surveys were excluded.

All producers were initially contacted by phone with the General Survey (defined below). After completing the General Survey, producers who were interested were emailed a link to the second part of the survey with follow-up questions. Producers that could not be contacted by phone (i.e., if only an email address was provided) were emailed a link to the Combined Survey (defined below) that contained the initial General Survey and follow-up questions. The response rate was 41% of the sampling frame. Producers who used to operate an AMS farm, but later abandoned the technology were not included in the study (n = 3). Producers were not selected based on how long they had their AMS. Including a range of producers from the earliest adopters to those who were still transitioning provided a spectrum of how the transition process has changed with time, thereby offering additional comparative detail.

2.3.2 General Survey, Follow-up and Combined Survey

A mixed-methods survey (titled 'The General Survey'; Appendix 1) was developed to obtain information on factors that may have been affected by transitioning to AMS (changes to the facility, employee management, milk production and quality, milking labour management), current milking statistics (average number of milkings/d), cow training, challenges and solutions experienced during the transition, changes in quality of life, and level of satisfaction with their AMS. Questions from this survey were also made available as part of a more detailed survey called 'The Combined Survey' (Appendix 2). The Combined Survey contained all questions from the General Survey, more detailed questions on the topics covered in the General Survey, in addition to new questions related to cow health, participation in milk recording programs, and

the use of the Canadian Dairy Code of Practice. The second part of the survey was provided as a follow-up to the General Survey (i.e., the follow-up solely consisted of questions unique to the Combined Survey). The question-answer formats ranged from single choice of multiple options, multiple choices of multiple options, fill in the blank, and free form open-ended questions.

The number of respondents per question varied depending on which survey the question was presented in and because respondents were given the option to answer or skip any question. The total number of respondents for the General Survey questions was 217. The total number of respondents for the follow-up questions, or the questions specific to the Combined Survey, was 69.

2.3.3 Statistical Analyses

All statistical analyses were performed with R version 3.2.2 (The R Foundation for Statistical Computing Platform, 2015). Statistical significance was considered at a *P*-value < 0.05. Due to the exploratory nature of the project, the data analyses primarily included descriptive statistics (means, SD, medians, 1st – 3rd quartiles, percentages). Results with normal distribution are presented as means $\pm$ SD. Results with non-normal distribution are presented as medians with 1st – 3rd quartiles (**IQR**).

In cases where provincial comparisons of results were made, only provinces with > 10 respondents were included. Comparisons of the brand were also made. However, due to the small sample sizes of Insentec and BouMatic users, comparisons were only made between Lely and DeLaval users. Comparisons between categorical data (e.g., when comparing perceptions of change in lameness, which was answered as either increased, decreased, or stayed the same, after transition by brand) were computed with chi-square test or, for cases that involved frequency

counts of less than five, Fisher's exact test. To compare ≥ 3 group means for normally distributed variables, ANOVA and Tukey's post-hoc procedure were used. A two sample t-test was used when comparing only 2 group means. Kruskal-Wallis test with Dunn's post-hoc test were used to compare ≥ 3 group medians of varibles that were not normally distributed and for ranked variables. Wilcoxon Rank Sum and Signed Rank test was used when comparing only 2 medians. Differences between paired groups (e.g., differences in herd size, number of employees, and time devoted to milking-related activity) were tested by using a paired t-test. When analyzing variables with time since transition to AMS, respondents in their first two years of transition were grouped together and compared with those who transitioned > 24 mo ago. A two-year time frame was chosen based on the average transition periods used in AMS literature when comparing milking variables before and after the adoption of AMS, and as a result of sample sizes available from our data set.

Inductive, thematic analysis was used to analyze open-ended questions. In other words, responses for open-ended questions were coded for themes (patterns across the data set) that were then quantified with the purpose of describing how common those themes were among our respondents (Green and Thorogood, 2013).

2.4 Results

2.4.1 Respondent Demographics

Overall, 217 AMS producers out of 530 AMS producers in our sampling frame were surveyed in 8 provinces across Canada (Table 2.1). Seven farms (3%) had never owned/operated a dairy farm prior to their current AMS dairy farm. The range for time since transitioning to AMS was 1 to 170 mo. Median age of Lely robots was 29 mo (IQR: 15 – 53 mo) and median age

of DeLaval robots was 34 mo (IQR: 21 – 68 mo). Herd size (lactating cows) ranged from 35 to 550 cows. Median herd size was 85 cows, with no differences between brands.

Results represent information provided by full owners (49%), part owners (48%) and employees responsible for the herd (3%). Primary decision makers, or producers who were the head of the farming operation, created the larger portion of the sample (89%). Sixty-nine percent of producers had complete or partial college or university education. Survey respondents consisted mostly of males (81%). Twenty-seven percent of producers were < 35 years of age, 28% were between 35 and 45, 30% were between 46 and 56, and 15% were > 56 years old. There was no difference in response rates between age groups.

2.4.2 Housing, Farm Management and Feed Practices

When transitioning to AMS, 55% of producers (118) built new barns. Of these, 71% also changed housing systems. Of the 96 producers who did not build a new barn, only 17% changed housing system. Overall, 53% of respondents did not change housing system. For those who changed housing system, 86% switched from tie-stall to free-stall, 5% from bedded-pack to free-stall, and 10% from tie-stall or free-stall to bedded-pack. A larger percentage of QC producers had to change housing system compared to producers in AB and ON (Table 2.1). Free-stall AMS barns were more predominant (91%) than bedded-pack AMS barns (9%). Most farms (90%) used a free-flow traffic system rather than a directed traffic system (10%).

Median lactating-cow herd size increased by 10% from 77 (IQR: 55 – 110) to 85 (IQR: 58 – 116) lactating cows, after transitioning to AMS ($P = 0.002$). Forty percent of farms had one robot, 43% had two, 10% had three, and 7% had more than four robots. Mean ($\pm$ SD) number of cows/robot was 51 $\pm$ 9 (range: 27 – 75 cows/robot; Figure 2.1). Most AMS producers (64%)

managed their lactating cows in one group, although the number groups ranged from one to five. For those who managed their lactating cows in multiple groups (n = 25 respondents), 68% reported having specific criteria for grouping. Criteria included: separating out fresh, first lactation, and 2^+ lactation cows (50% of respondents); separating special needs and older lactating cows from problem-free and younger lactating cows (19%); sorting by size and age (13%); sorting by milking speed and milking visit frequency (13%); and separating their best pedigree cows (6%).

The farms had a median of 1.0 cow/stall (IQR: 0.8 – 1.0 cows/stall). Lying stalls had a median width of 122 cm (IQR: 117 – 122 cm). Rubber mats/mattresses/water mattresses were more commonly used as stall bases than the use of deep-bedding on AMS farms (78% versus 22%, respectively). Of the rubber mats/mattresses/water mattresses users (n = 53 respondents), 96% used bedding on top of the mat/mattress. Half of the producers who used bedding on top of stall mats/mattresses used shavings or sawdust, while the other half used other bedding (e.g., straw, manure or gypsum bedding). Stalls were cleaned out (i.e., dirty bedding and manure scraped out) a median of twice a day (IQR: 2 – 3 times/d), and fresh bedding was added as often as once a day to once every 3 wk. Alleyways were cleaned a median of 8 times/d (IQR: 6 – 12 times/d). Automatic manure scrapers were more common on AMS farms (81%) than the use of slatted floors (15%) or scraping by tractor/skid-steer (4%).

After transitioning to AMS, 36% of producers (39 respondents) changed feeding systems (e.g., individual components to a mixed ration). At the time of the survey, 83% of AMS farms provided a mixed ration and 17% provided individual feed components. The number of times feed was delivered to cows stayed the same for 74% of farms after transition to AMS, decreased for 14% and increased for 12%. Feed was delivered to the feed bunk a median of 2 times/d (IQR:

1 – 2 times/d). The frequency that feed was pushed up to the bunk remained the same for 59% of farms, increased for 38%, and decreased for 2%. Feed was pushed up in the feed bunk 4 times/d (IQR: 2 – 9 times/d). The mean amount of space provided per cow along the feed bunk was 61 $\pm$ 21 cm/cow. Headlocks were more common on AMS farms (55% of respondents) than rails (33%), or other feed barriers such as feed stalls (12%). Farms had a median of 1.0 headlock/cow (IQR: 0.8 – 1.1 headlocks/cow), with median headlocks widths of 61 cm (IQR: 61 – 61 cm). Between water troughs, bowls or the use of both, the most common water delivery method on AMS farms was water troughs, which was used by 90% of farms. There was a median of 26 cows/trough (IQR: 20 – 30 cows/trough). Farms that used both troughs and bowls were not included in calculating this median.

2.4.3 Cow Health

Since transitioning to AMS, 66% of producers had changed their health management practices. 80% of producers perceived that illness detection was easier with an AMS because of the amount of information the robots provide on each animal (e.g., udder health reports, cow weight and temperature measurements, milking reports, activity and rumination reports; 77% of respondents), and because of the alarms that notify producers of issues (23% of respondents). AMS made health detection more difficult for 19% of producers. Responses did not differ by age of robots, although overall percentage of producers who reported that health detection was more difficult was lower for Lely owners versus DeLaval owners (Table 2.2). The producers who found health detection more difficult in AMS indicated difficulties as a result of no longer seeing every cow (and her udder) twice a day (67% of respondents) and needing to rely on technology (i.e., the AMS) to detect most health issues (33% of respondents). The most common health

26

issues that were reported to have occurred since transitioning to AMS were lameness and mastitis (Table 2.3). The most common health issues reported to have improved since transitioning were reproduction/fertility, mastitis and lameness (Table 2.3). There were no differences in perceptions of change in rates of lameness, mastitis, fertility and culling according to the time since transition (Table 2.4).

Rate of lameness after transitioning to AMS was reported to have decreased for 42% of producers, stayed the same for 38%, and increased for 20%. Forty-seven percent of producers changed housing systems at the same time as transitioning to AMS. The proportion of these producers that noticed an increase in lameness (17% of respondents) was greater than those that experienced an increase in lameness but did not change housing system (5% of respondents; $P <$ 0.001). Producers reported an increase in milk yield despite their perceived change in lameness: there was no difference in the distribution of producers who stated an increase in milk yield in tandem with an increase (21% of respondents), a decrease (44%), or no change in lameness (35%). Since transitioning to AMS, 74% of farms indicate that they have been more able to detect lame cows as a result of having more time observing cows and automatic detection (e.g., lame cows become fetch cows). AMS farms reported to have implemented various management practices, such as footbath protocols, hoof trimming, and improving cow comfort to deal with lameness (Figure 2.2). Thirty percent of producers reported that lame cows were culled more often after transitioning to AMS.

Rate of clinical mastitis was reported to have decreased for 49% of producers, stayed the same for 38%, and increased for 13%. There were more producers who reported an increase in milk yield in tandem with a decrease in mastitis (54% of respondents), compared to those who reported an increase in milk yield along with an increase (13%) or no change in mastitis (33%; P

= 0.002). The most common method used on AMS farms of detecting clinical mastitis was to rely on AMS-generated reports on milk conductivity, blood in milk, change in production, and SCC for alarms, and to follow-up with a manual check (either using a California mastitis test or manual stripping of milk). Reported change in bacterial count varied with 40% of producers perceiving no change, 34% a decrease, and 26% an increase. There was a difference in the distribution of producers who reported a change in bacterial count between Lely and DeLaval producers; a larger proportion of DeLaval producers reported an increase in bacterial count and a larger proportion of Lely producers reported no change ($P = 0.01$). Thirty-eight percent of producers reported that mastitis cows were more likely to be culled after transitioning to AMS.

Conception rate was reported to have increased for 63% of producers, stayed the same for 31%, and decreased for 6%. Ninety percent of AMS farms used activity/behavior monitors. The most common monitors used were activity collars (used by 51% of farms) and combination activity and rumination collars (47% of farms). Leg activity monitors were only used by 2% of farms. The approach to heat detection changed for 63% of AMS farms. Those producers reported relying on computer information to reveal heats and less on visual observations of heat. Activity/behavior monitors were the primary tools for heat detection on 76% of AMS farms. Methods of heat detection used by the other 24% of respondents included solely visual observations for heat, use of a timed artificial insemination program, and hormone testing with Herd Navigator, software that aims to improve monitoring and intervention in reproduction, udder health, feeding and feeding-related conditions (Herd Navigator; Lattec I/S, Hillerød, Denmark). Although the main use for activity/behavior monitors was for heat detection, some farms also used monitors to detect metabolic disorders, lameness, and mastitis.

Culling rate was reported to have stayed the same for 59% of producers, increased for 25%, and decreased for 16%. There was a difference in the distribution of reported change in culling rate between Lely and DeLaval producers ($P = 0.003$). More Lely producers perceived no change in culling rate than DeLaval producers (45% versus 14%) and more DeLaval than Lely producers perceived an increase in culling rate (17% versus 7%). Median percentage of a lactating herd culled because of the transition was 2% (IQR: 0 – 4%). The most common reasons for culling after the transitioning to AMS were: reproduction/fertility issues, poor udder health, lameness and other feet/leg issues, and teat placement/udder conformation (Table 2.5).

2.5 Discussion

This is the first study to provide comprehensive information regarding the perceived impacts of transitioning to AMS on housing, farm management (inclusive of feeding and cleaning practices), and cow health. The majority of producers perceived a positive transition to AMS. Farms were able to increase herd size while maintaining the same cleaning and feeding practices. Changing health management practices with AMS was necessary for most producers, but the majority reported health detection to be easier. AMS increased conception rate, but had little effect on reported rates of lameness and mastitis.

Median herd size of surveyed AMS farms was similar to the overall average herd size, 80 cows, of Canadian dairy farms (Canadian Dairy Information Centre, 2016). Farms operated with a mean number of cows/robot that fell within the recommendation of 50 to 60 cows/robot (DeLaval International AB, 2008; Hulsen and Rodenburg, 2008.).

Similar to other AMS studies (Bentley et al., 2013; Woodford et al., 2015) it was more common for producers to build new facilities for the AMS than to retrofit an existing barn.

Although the percentage is slowly decreasing, 72% of Canadian dairy farms still use tie-stalls (Barkema et al., 2015). Changing housing system was more common in QC than other provinces, as 88% of QC dairy farms house cows in tie-stalls (Canadian Dairy Information Centre, 2016). Feed bunk space per cow met industry standards of 60 cm/cow. Frequency of feed delivery on AMS farms was similar to a previous study; however, the average frequency of feed push-up at the bunk was double in our study (Deming et al., 2013). Stocking density met the Canadian Dairy Code of Practice's (**DCOP**) recommended best practice of 1 cow/stall (National Farm Animal Care Council, 2009). Stalls in our study were, on average, wider by 2 cm compared to what was reported in a recent study with 36 AMS farms in Canada and the States (Westin et al., 2016). Stall widths in the current study met the minimum recommended width for cows weighing between 545 and 636 kg according to the DCOP (National Farm Animal Care Council, 2009). Similar to the Westin et al. (2016) study, the use of rubber mats and mattresses was more common on AMS farms than the use of deep-bedding. In addition, our results for stall cleaning frequency (average of 2×/d) was comparable to the results of the Westin et al. (2016) study, where 88% of AMS farms cleaned stalls $\geq$ 1×/d. Results on the DCOP from the current study can be found in Appendix 3.

Having a vast amount of information provided by the AMS was documented to improve health detection in the current study, as well as others (see review by Barkema et al., 2015). However, some producers reported it to be more difficult to detect changes in cow health. A reason for this may be that despite theoretically having more time to observe their cows, AMS producers may not actually be among the cows as often to visually detect changes (e.g., cows in estrous; Kruip et al., 2002). Additionally, learning to understand and use the vast amount of

information collected by the robot may prove to be an exceptional challenge when transitioning to AMS (Bewley and Russell, 2010; Butler et al., 2012).

Producers reported no change in rate of lameness with the transition to AMS, although a recent study observed a lower prevalence of lameness in their AMS herds than what was previously documented in Canadian dairies with conventional milking systems (**CMS**; Westin et al., 2016). Producers from the current study found lameness easier to detect with AMS, which is not unexpected since lame cows visit the AMS less frequently, or are less likely to voluntarily visit the robotic unit at all, than those that are not lame (Bach et al., 2007; Borderas et al., 2008; Miguel-Pacheco et al., 2014). Borderas et al. (2008) showed that milk yield is negatively affected when lameness causes a decrease in AMS visits. Interestingly, most producers who perceived an increase in lameness still reported an increase in milk yield across the lactating herd. Hillerton et al. (2004) reported that lameness prevalence increased considerably a year after farms transitioned to AMS (unlike our study that determined no difference in perceptions of change in lameness with time) but concluded that poorer locomotion after switching to AMS was likely due to the change in housing that had occurred at the same time as the transition. In support of that conclusion, this study determined that changing housing system at the same time as the transition to AMS resulted in higher reports of increased lameness. Thus, Canadian dairies that convert from tie-stall to free-stall barns at the same time as the transition to AMS should keep in mind that barn design and management will have a greater impact on cow locomotion than the change in milking system itself.

Almost half the respondents of our survey indicated a decrease in clinical mastitis with the transition to AMS, and the next largest proportion of producers indicated no change. This was complementary to the findings of Hovinen et al. (2009) where the frequency of mastitis

treatments decreased from 4.8/10,000 cow-days with CMS to 4.0/10,000 cow-days in AMS farms, although the difference was not significant. Furthermore, it is worth noting that a significant proportion of producers who reported a decrease in incidence of clinical mastitis also indicated an increase in milk yield (54% of respondents). This agrees with the idea that better udder health is associated with greater milk production (Neijenhuis et al., 2010). Perceptions of change in mastitis did not differ according to time since transition. To date there is no literature documenting how the rate of clinical mastitis changes according to how long a herd has been using AMS.

Geometric mean total bacterial count has been reported to increase by 4,000/mL to 11,000/mL after transitioning to AMS (Klungel et al., 2000; Rasmussen et al., 2002; de Koning et al., 2003). Variation may be due to the range of transition periods used by these studies. Rasmussen et al. (2002) compared data collected 1 yr before AMS to those collected 1 yr after AMS was introduced on the same farms. Klungel et al. (2000) compared AMS farms that have been in operation for at least 1 yr to (different) farms that operated CMS. Lastly, de Koning et al. (2003) compared farm data collected up to 4 yr before transition to data collected between zero to > 2 yr after the same farms transitioned to AMS. In contrast, producers in our study reported no change in bacterial count after transitioning to AMS. The studies that have reported an increase in bacterial count when transitioning to AMS are more than 10 yrs old. It is conceivable that the AMS systems itself and management of these systems has improved over these years. To substantiate that data, before and after transitioning need to be compared.

It has been hypothesized that AMS would negatively impact cow fertility, the ability to conceive a calf, as a result of an expected increase in risk of negative energy balance (**NEB**; Kruip et al., 2002). Kruip et al. (2002) suggested that higher milking frequencies in AMS result

in greater milk yield, but not necessarily a proportional increase in feed intake, which may consequently lead to NEB. A NEB results in lower glucose and insulin levels, which are important factors in fertility (Kruip et al., 2000). However, in agreement with several experimental studies that have reported no negative effects on conception rate despite increased milking frequency and milk production with AMS (Barnes et al., 1990; Devir et al., 1993; Kruip et al., 2000; 2002), a large proportion of producers in our survey reported an increase in conception rate.

Unusual udder conformation, poor temperament, and issues with legs and feet can negatively affect the usage of AMS units, and may increase culling rate (Meskens et al., 2001). However, our results agree with Bentley et al. (2013), who reported little change in culling rate with the transition to AMS. Surveyed individuals in our study reported culling an average proportion of cows that were not able to adapt to the AMS compared to the documented culling range of 0 to 3% (Rodenburg, 2002).

A larger proportion of DeLaval respondents found health detection more difficult with AMS, perceived an increase in bacterial count, and reported a higher culling rate, compared to Lely respondents. It was speculated that confounding variables such as age of AMS units and geographical distribution of AMS brands across Canada could have influenced these differences. However, there were no age differences between brands and the distribution of the 2 brands was similar in all provinces, except Alberta. There may be some bias due to differing levels of participation of each brand, as well as in each province. The distribution of brands and surveyed AMS farms/province were not always representative of the true distributions across Canadian provinces. In a milk quality study by de Koning et al. (2003), 32% of the variation in total bacterial count was explained by difference between brands of AMS, although exact brands were

not mentioned. To our knowledge, there is no literature that addresses specific brand differences in these factors or reasons for possible differences between brands of AMS.

Like most surveys, there was a potential for misinterpretation of questions, recall bias (an issue of remembering accurately), and social desirability bias (the tendency to respond differently in the presence of an interviewer so as to appear in favourable light; Green and Thorogood, 2013). Both phone and in-person surveys were conducted, but risk for interviewer bias was minimized by asking questions strictly as they were written in the final version of the survey and only providing standardized prompts when necessary. Producers may have been influenced by post-product rationalization, a cognitive bias through which a purchaser of an expensive product looks past any product faults as a way to justify their purchase (Cohen and Goldberg, 1970). This bias may have distorted results to show more improvements on farm since transitioning to AMS. Lastly, it should be noted that the possible differences after transitioning to AMS may not be a result of just the new milking system, but also of the changes in housing and management that accompanied that change.

2.6 Conclusions

Overall transition to AMS was perceived as successful for Canadian dairy producers. With necessary changes to housing to accommodate the AMS, farms were able to increase herd size while keeping cleaning and feeding practices the same. Producers needed to change health management practices with AMS, but the majority reported health detection to be easier. AMS increased conception rate, but had little effect on reported rates of lameness and mastitis. Findings from this project provide a benchmark of the impacts of AMS on important aspects of Canadian dairy farming, as well as provide producers, AMS manufacturers, veterinarians and dairy advisors with more detailed knowledge on what to expect when transitioning to AMS.

Table 2.1: Characteristics of the participating Canadian automatic milking system (AMS) farms

Item	Province[1]							Overall[2]
	BC	AB	SK	MB	ON	QC	Maritimes	
Total surveyed (% of all respondents)	8 (4%)	43 (20%)	7 (3%)	12 (6%)	73 (34%)	66 (30%)	7 (3%)	217
Total in sampling frame (% of sampling frame)	23 (35%)	59 (73%)	13 (54%)	56 (21%)	136 (54%)	211 (31%)	32 (22%)	530 (41%)
Changed housing system (% respondents)	25%	38%[a]	33%	25%	38%[a]	74%[b]	0%	47%
Median herd size (lactating cows)	83	108[a]	101	93	78[ab]	75[b]	57	85
1st – 3rd quartile	62 – 108	86 – 140	93 – 103	66 – 143	55 – 120	55 – 110	53 – 88	59 – 116
Median AMS units/farm	2	2[a]	2	2	2[b]	2[b]	1	2
1st – 3rd quartile	1 – 2	2 – 3	2 – 2	1 – 2	1 – 2	1 – 2	1 – 2	1 – 2
Mean number of lactating cows/robot $\pm$ SD	55 $\pm$ 9	51 $\pm$ 7[a]	50 $\pm$ 5	56 $\pm$ 8	50 $\pm$ 9[a]	51 $\pm$ 10[a]	49 $\pm$ 7	51 $\pm$ 9
Brand of AMS (% respondents)								
Lely	100%	40%	71%	75%	90%	82%	86%	76%
DeLaval	0%	49%	14%	25%	10%	17%	14%	21%
Other[3]	0%	12%	14%	0%	0%	2%	0%	3%
Median months since transition to AMS	43	29[a]	44	49	30[a]	27[a]	15	30
1st – 3rd quartile	22 – 47	14 – 45	12 – 62	27 – 69	17 – 56	13 – 66	12 – 27	15 – 57

[1] Only AB, ON and QC could be tested for provincial differences due to small sample size in other provinces.
[2] Overall values included one anonymous respondent.
[3] Other brands included BouMatic, Insentec and unspecified.
[a,b] Medians and means within a row without a common superscript are significantly different ($P < 0.05$).

Table 2.2: Percentage of producers by brand of AMS, organized by months since transition, with changes in health management after transitioning to AMS

Item and Months since Transition[1]	Brand	
	Lely	DeLaval
Changed health mgmt. after transition		
$\leq$ 24 mo[2]	59%	100%
> 24 mo[3]	65%	69%
Overall mean	63%	77%
Health detection has become easier with AMS		
$\leq$ 24 mo	76%	100%
>24 mo	88%	69%
Overall mean	84%	77%
Health detection has become harder with AMS		
$\leq$ 24 mo	6%	20%
> 24 mo	12%	44%
Overall mean	10%[a]	38%[b]
Changed approach to heat detection with AMS		
$\leq$ 24 mo	53%	50%
> 24 mo	73%	67%
Overall mean	65%	62%
More able to detect lame cows with AMS		
$\leq$ 24 mo	76%	100%
> 24 mo	77%	69%
Overall mean	77%	77%
More likely to cull lames cows with AMS		
$\leq$ 24 mo	18%	67%
> 24 mo	31%	31%
Overall mean	26%	41%
More likely to cull cows with mastitis with AMS		
$\leq$ 24 mo	29%	50%
> 24 mo	38%	44%
Overall mean	35%	45%

[1] There were no differences in proportions for each item by time since transition (within each brand).
[2] Lely: n = 17 and DeLaval: n = 6.
[3] Lely: n = 26 and DeLaval: n = 16.
[a,b] Means within a row without a common superscript are significantly different ($P < 0.05$).

Table 2.3: Health issues that have occurred or improved since transitioning to AMS (respondents listed ≥ 1 health issue that had occurred/improved on their farm)

Item	Number of respondents	Respondents (%)
Health issues that have occurred since transition (52 respondents)		
Lameness	32	62
Mastitis	18	35
None	13	25
Increased SCC	6	12
Other[1]	6	12
Reproduction/fertility	5	10
Udder health	2	4
Health issues that have improved since transition (61 respondents)		
Reproduction/fertility	21	34
Mastitis	18	30
Lameness	15	25
Udder health	7	11
None	7	11
Cow comfort	6	10
Decreased SCC	5	8
Less DA	4	7
Other[2]	4	7
Body condition	3	5
Transition cow health	3	5
Ketosis	2	3

[1] Other health issues that have occurred since transition included: afterbirth, decreased transition cow health, increased total bacterial count, more muscle injuries, metritis, and ketosis.
[2] Other health issues that have improved since transition included: fewer injuries, earlier detection of sick cows, less milk leakage, and rumination activity.

Table 2.4: Percentage of producers with respective perceptions of change in cow health after transitioning to AMS, organized by months since transition to AMS (n = 24 respondents for ≤ 24 mo, n = 42 respondents for > 24 mo)

Months since Transition[1]	Perceptions of Change (% respondents)		
	Increased	Decreased	Stayed the Same
Rate of lameness			
≤ 24 mo	21	54	25
> 24 mo	21	36	43
Overall mean	20	42	38
Rate of clinical mastitis			
≤ 24 mo	4	42	54
>24 mo	17	52	31
Overall mean	13	49	38
Bacterial count			
≤ 24 mo	25	29	46
> 24 mo	39	24	37
Overall mean	34	26	40
Conception rate			
≤ 24 mo	71	0	29
> 24 mo	61	10	29
Overall mean	63	6	31
Culling rate			
≤ 24 mo	17	13	71
> 24 mo	31	19	50
Overall mean	25	16	59

[1] There were no differences in distributions of perceived change for each item by time since transition.

Table 2.5: Reasons for culling after transitioning to AMS, from most common to least (n = 64)

Reasons for culling	Number of respondents	Respondents (%)
Reproduction/fertility issues	38	59
Udder health (mastitis, high SCC)	33	52
Lameness and other feet/leg issues	30	47
Teat placement/udder conformation	27	42
Behaviour/temperament	17	27
Low production and milking speed	16	25
Age	7	11
Other causes unrelated to AMS (e.g., being unable to adapt to stalls, injury)	6	9
Other health issues (e.g., Johne's Disease)	2	3
Good cull cow prices	1	2
Too many cows	1	2
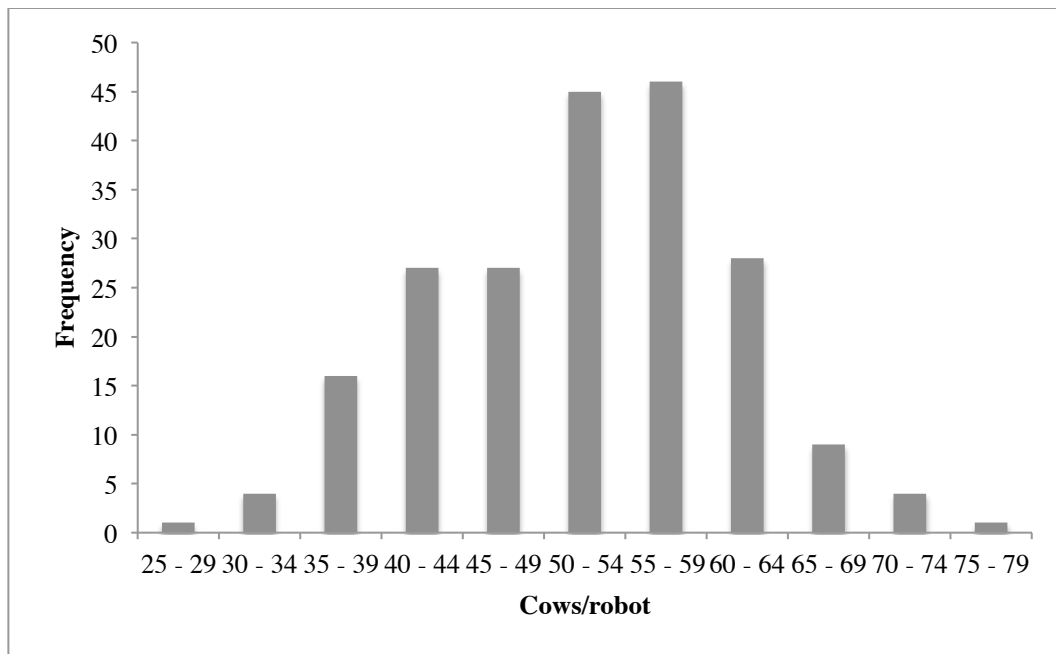
Figure 2.1: Histogram of number of cows/robot on AMS farms, where median number of cows/robot was 52 (range of 27 to 75 cows; 208 respondents).
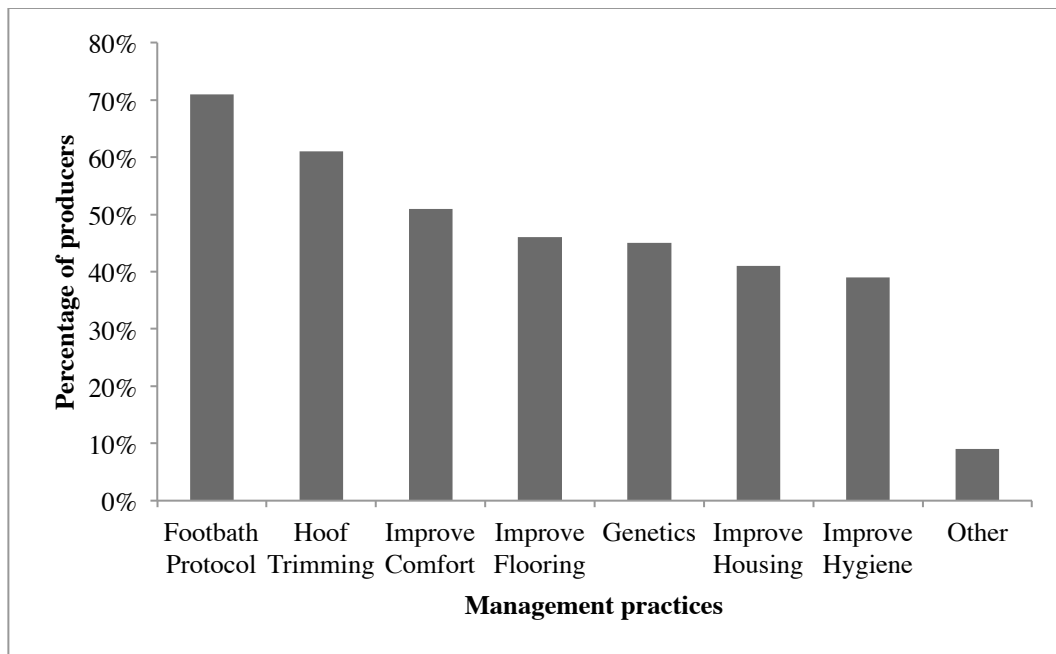
Figure 2.2: Management practices implemented to deal with lameness on AMS farms (69 respondents per item).

Chapter Three: **Impact of Automatic Milking Systems on Producers' Reports of Milking Labour Management, Milk Production and Milk Quality in the Canadian Dairy Industry**

3.1 Abstract

Automatic milking systems (AMS), or milking robots, are becoming widely accepted as a milking technology that reduces labour and increases milk yield. However, the reported amount of labour saved, changes in milk yield, and milk quality when transitioning to AMS vary widely. The purpose of this study was to document the impact of adopting AMS on Canadian farms with regards to reported changes in milking labour management, milk production, milk quality, and participation in dairy herd improvement (DHI) programs. A total of 217 AMS producers from 8 Canadian provinces were surveyed. On average, after adopting AMS the number of employees (full-time and part-time combined) decreased from 2.5 to 2.0, whereas time devoted to milking-related activities decreased by 62% (5.2 to 2.0 h/d). Median milking frequency was 3.0 milkings/d and robots were occupied on average 77% of the day. Producers went to fetch cows a median of 2 times/d, with a median of 3 fetch cows or 4% of the herd per robot/d. Farms had a median of 2.5 failed or incomplete milkings/robot/d. Producers reported an increase in milk yield and little effect on milk quality. Mean milk yield on AMS farms was 32.6 kg/cow/d. Median bulk tank SCC was 180,000 cells/mL. Median milk fat on AMS farms was 4.0% and median milk protein was 3.3%. At the time of the survey, 67% of producers were current participants of a DHI program. Half of the producers who were not DHI participant had stopped participation as a result of the transition to AMS. Findings from this study can act as a benchmark for future Canadian dairy producers who decide to switch to AMS and aid in more successful transitions by providing information on what to expect with the change.

3.2 Introduction

Currently, there are about 25,000 dairy farms with automatic milking systems (**AMS**), or milking robots, in the world (Barkema et al., 2015). In 2015, there were 530 AMS farms in Canada (Chapter 2). An AMS has the benefit of reducing labour (Bentley et al., 2013; Woodford et al., 2015), while increasing milk production (Bernier-Dodier et al., 2010; Hansen, 2015). However, milk quality may be compromised with this technology (Hovinen and Pyörälä, 2011).

Labour requirements are reduced with AMS because teat cleaning, milking and separation of abnormal milk are integrated into the robotic unit. Labour is also modified with AMS, as producers need to be on-call for alarms (fetch cows, robot maintenance, etc.) and must adopt more data-based methods for identifying health and welfare issues (de Koning, 2010; Butler et al., 2012). Labour savings with AMS in Europe have been reported to range from 18 to 38% (Sonck, 1995; Mathijs, 2004; Bijl et al., 2007), however these estimates have yet to be made for Canadian AMS farms.

The average reported increase in milk yield with AMS ranges from 2 to 25% (Reinemann and Davis, 2002; de Koning and Rodenburg, 2004; Bernier-Dodier et al., 2010). The positive association between milk yield and AMS may be a result of more frequent milkings/d when using AMS (Erdman and Varner, 1995; Melin et al., 2005). However, not all researchers agree that milk frequency and milk yield are related (Migliorati et al., 2005; Spolders et al., 2004).

Milk quality has been reported to be slightly, but significantly, lower in AMS farms, with the poorest quality found in the first 6 mo after introducing AMS (van der Vorst et al., 2002). Several studies have shown that freezing point, FFA, and total bacterial count are higher after transition to AMS, whether farms are in their first 6 mo, or 1 to 3 yr of transition (Klungel et al.,

2000; Meskens et al., 2001; van der Vorst et al., 2002). The effect of AMS on bulk tank SCC (**BTSCC**), however, has been variable. Bulk tank SCC either did not change (Zecconi et al., 2003; Salovuo et al., 2005; Helgren and Reinemann, 2006), increased (Kruip et al., 2002; Rasmussen et al., 2002; de Koning et al., 2003), or decreased (Shoshani and Chaffer, 2002; Bentley et al., 2013; Tousova et al., 2014).

Dairy herd improvement programs offer a wide range of services such as collecting and analysing herd data and milk samples, and consolidate information for producers to use to improve herd management and milk quality, as well as for national evaluations of dairy cattle and milk quality (Valacta, 2015; CanWestDHI, 2016). Enrolment, however, is entirely voluntary and services come with a cost. The program's effectiveness for national evaluations depends on producer participation. There has been concern regarding reduced participation in DHI programs with the growing popularity of AMS because this technology provides a profuse amount of data per cow that was not previously available to producers on farm (Ontario Ministry of Agriculture, Food and Rural Affairs, 2010). Once producers make the large investment for an AMS, it is no surprise that they may be reluctant to pay for DHI services. To date, there has been no published documentation of change in the use of DHI programs with the transition to AMS.

The objective of this study was to determine producers' reports of change in milking labour management (milking-related activities), milk production, milk quality, and the use of DHI programs on Canadian farms after the transition to AMS.

3.3 Materials and Methods

This research was part of a larger study aimed at determining the impact of transitioning to AMS on producers' perceptions of farm management and cow health in the Canadian dairy

industry. As such, detailed descriptions of the methodology are presented in Chapter 2. Institutional human ethics certification was acquired prior to contacting participants (University of Calgary, certification no. REB14-0149_MOD1). Participants provided consent before surveys were conducted.

3.3.1 Farm Selection and Data Collection

Alberta Milk (Edmonton, AB, Canada), Dairy Farmers of Manitoba (Winnipeg, MB, Canada), Lely Canada (Woodstock, ON, Canada) and DeLaval Canada (Peterborough, ON, Canada) provided the contact information for producers currently using AMS. We compiled the contact information to create our sampling frame. Surveys were conducted from May 2014 to the end of June 2015. All producers in our sampling frame (total of 530 AMS producers) were contacted and data was collected by telephone, email and in person on those willing to participate. AMS respondents were from British Columbia (**BC**; n = 8), Alberta (**AB**; n = 43), Saskatchewan (**SK**; n = 7), Manitoba (**MB**; n = 12), Ontario (**ON**; n = 73), Quebec (**QC**; n = 66), New Brunswick, and Nova Scotia. New Brunswick and Nova Scotia were grouped together and are referred to as the 'Maritimes' (n = 7). Producers were initially contacted by phone with the General Survey (described below). After completing the General Survey, producers who were interested were emailed a link with follow-up questions. Producers who could not be contacted by phone were emailed a link to the Combined Survey (described below), which contained the General Survey and follow-up questions. Surveys that were terminated before completion were excluded from the study.

3.3.2 Surveys

The General Survey addressed the following: changes to housing, milk production, milk quality, and milking labour management, current milking statistics, experience with cow training, challenges and solutions experienced during the transition, changes in quality of life and overall level of satisfaction with AMS. The Combined Survey contained the following: the General Survey questions, more detailed questions on topics covered in the General Survey, in addition to new questions related to cow health, participation in a DHI program, and use of the Dairy Code of Practice. The follow-up to the initial survey solely consisted of questions unique to the Combined Survey. Sample sizes per question varied depending on which survey was answered and because respondents had the option to skip questions. The total number of respondents for General Survey questions was 217, while the number of respondents for the follow-up questions, which were specific to the Combined Survey, was 69.

3.3.3 Statistical Analyses

All statistical analyses were performed with R (version 3.2.2; The R Foundation for Statistical Computing Platform, 2015). A P-value < 0.05 was considered statistically significant. Data analyses primarily included descriptive statistics (means, SE, medians, 1st – 3rd quartiles, percentages), where normally distributed results are presented as means $\pm$ SE whereas results with non-normal distribution are presented as medians with 1st – 3rd quartile (**IQR**).

Due to the small number of Insentec and BouMatic users, only data of farms using Lely and DeLaval AMS were used where comparisons between brands were made. Chi-square test or, for cases that involve frequency counts less than 5, Fisher's exact test was used to compare categorical, frequency data (e.g., when comparing perceptions of change in milk yield, which

was answered as either increased, decreased, or stayed the same, after transition by brand). ANOVA and Tukey's post-hoc procedure were used to compare ≥ 3 group means for normally distributed variables, and a two sample t-test was used for comparing two group means. Kruskal-Wallis test with Dunn's test post-hoc were used to compare ≥ 3 group medians of variables that were not normally distributed and Wilcoxon Rank Sum and Signed Rank test when comparing two medians (e.g., when comparing average milking frequency/d by brand). Differences between paired groups (e.g., number of employees and time devoted to milking-related activity before and after the transition) were tested by pairwise comparison using a paired t-test. A linear regression was used to assess the strength of associations between change in number of employees with change in herd size, as well as between milk yield and BTSCC with milking frequency, herd size, cows/robot (for farms that stayed within the AMS dealer recommendation of < 60 cows/robot), and time since transition to AMS. A subcategory of respondents in their first 2 yr of transition was used when analyzing relationships of variables with time since transition to AMS. The underlying assumptions for linear regressions were assessed prior to running the models. Bulk tank SCC was log transformed to meet the assumptions.

3.4 Results

3.4.1 Milking Labour Management

Mean number of employees (full time and part time employees combined) decreased by 20% with the adoption of AMS (Table 3.1). Reported time devoted to milking-related activities (preparing and cleaning the AMS, fetching cows, and addressing alarms versus preparing and cleaning the parlour, and moving cows to the holding pen in conventional milking systems) also decreased with AMS (Table 3.1). DeLaval owners reported a mean decrease of 2.5 ± 0.3 h/d in

time spent on milking-related activities, while Lely owners reported a larger decrease of 3.4 $\pm$ 0.2 h/d (P = 0.005). Although the current time spent on milking-related activities was not different between the two brands: Lely owners spent 1.9 $\pm$ 0.1 h/d on milk-related activities and DeLaval owners spent 2.4 $\pm$ 0.3 h/d (P = 0.14).

3.4.2 Milk Production and Quality

Median milking frequency was 3.0 milkings/cow/d, with Lely owners reporting a higher milking frequency than DeLaval owners (Table 3.2). Robots were occupied on average 77% of the day. There was a median of 3 fetch cows/robot/d, which equated to fetching 4% of a herd/robot/d, and each cow was fetched a median of 2 times/d. Producers waited a median of 12 h (IQR: 10 – 12 h) before fetching early lactation cows, with a maximum waiting period of 15 h. Producers waited a median of 14 h (IQR: 12 – 15 h) for late lactation cows, with a maximum waiting period of 24 h. AMS farms reported 2.5 failed or incomplete milkings/robot/d.

After adopting AMS, 81% of producers reported that milk yield had increased. Milk fat and milk protein content were reported to have stayed the same for 56% and 79% of farms, respectively. Reported change in BTSCC varied with 43% of respondents stating a decrease, 37% noticing no change, and 20% reporting an increase. Distributions of reported change in milk yield, BTSCC, milk fat, and milk protein were not different between farms that transitioned $\leq$ 24 mo and > 24 mo to AMS (Table 3.3). Distributions of reported change were different between Lely and DeLaval owners for milk yield and milk fat content, but not for BTSCC or milk protein content (Table 3.4).

Overall, milk yield on AMS farms was 32.6 kg/cow/d, with no differences among AMS brands (Table 3.5). Median milk fat content on AMS farms was 4.0%, with DeLaval owners

48

reporting a higher percentage than Lely owners. Median milk protein content on AMS farms was 3.3%, with no differences by brand. Geometric mean BTSCC was 180,000 cells/mL, with no differences between the 2 predominant brands.

A simple linear regression was calculated to predict milk yield based on milking frequency with the robot. Milk yield increased 2.3 kg/cow/d for each additional milking visit (P = 0.002). Milk yield and time since transition to AMS were not associated ($\beta_1 = 0.02$, $P = 0.75$), and neither were milk yield and herd size ($\beta_1 = 0.003$, $P = 0.43$) or milk yield and cows/robot ($\beta_1 = -0.08$, $P = 0.06$). There was no association between log-transformed BTSCC and cows/robot ($\beta_1 = 0.004$, $P = 0.17$), log-transformed BTSCC and herd size ($\beta_1 = 0.001$, $P = 0.09$), or log-transformed BTSCC and time since transition to AMS ($\beta_1 = -0.008$, $P = 0.26$).

3.4.3 DHI Participation

At the time of the survey, 67% of producers were currently DHI participants. Of the 22 respondents who were not current participants, 11 (50%) were DHI participants prior to transitioning to AMS. Most producers (93%) were satisfied with the information that can be retrieved from the AMS computer program.

3.5 Discussion

This is the first study to provide comprehensive information regarding the impacts of adopting AMS on reports of change in milking labour management, milk production and quality, and participation in DHI programs in Canada. Farms reported an increase in milk yield with little effect on milk quality, and reduced the number of employees and time devoted to milking-related

activities after the transition to AMS. Two thirds of producers were participants of a DHI program at the time of the survey but adoption of an AMS appears to reduce participation.

The decrease in time devoted to milking-related activities after transition to AMS was similar to the 75% milking-labour savings documented in Iowa, USA, by Bentley et al. (2013). The number of employees also decreased with the transition to AMS in the current study, although the difference was small. A reason why the difference in number of employees before and after the transition was not larger may be that farms were reducing the amount of family labour first before decreasing the number of employees. This has also been suggested by Bijl et al. (2007) who found a significant but small decrease in number of employees (strictly external workers) when comparing AMS to conventional milking systems (**CMS**). Furthermore, since labour becomes more data-based with AMS (Butler et al., 2012), it is possible that a certain amount of time saved on milking labour is transferred to another type of labour that is more computer-oriented.

The average proportion of cows fetched per day (4%) was on the lower end of a previously documented range in Canada (4 to 25% of a herd; Rodenburg and House, 2007). In a study on a single farm, Munksgaard et al. (2011) documented an 83% occupation rate/d in both forced and free traffic AMS. Our study showed a lower occupation rate (77%) despite having a larger cows/robot ratio (51 cows/robot) than the Munksgaard et al. (2011) study (35 cows/robot). The respondents of the current study reported an average number of failed or incomplete milkings/d that was half the reported average of a recent North American AMS study (Tremblay et al., 2016). This difference in finding may be a result of comparing producers' reported values in the current survey study and AMS-generated data in the Tremblay et al. (2016) study.

The reported change in milk yield was similar to direct measurements of other studies (e.g., Wagner-Storch and Palmer, 2003; Hansen, 2015; Woodford et al., 2015): milk production increased with the transition from CMS to AMS. The average milk yield of 32 kg/cow/d is typical for North American AMS dairy farms (Tremblay et al., 2016). Similar to the results of DeVries et al. (2011), milk yield was positively associated with milking frequency in the current study. Melin et al. (2005) determined a 9% increase in milk yield when milking frequency increased from 2.1 $\pm$ 0.1 to 3.2 $\pm$ 0.1 times/d in an AMS with control gates and an open waiting area. Conversely, a study that increased milking frequency of AMS cows by adding flavoured and appetizing substances to feed delivered at the milking unit determined that milk yield was not affected by increased milking frequency (Migliorati et al., 2005). A more recent study suggests that improvements in milk yield, as a result of increased milking frequency with AMS, are limited to first-lactation cows (Spolders et al., 2004).

Milk fat and milk protein were reported to have stayed the same after transition to AMS, but BTSCC varied with farmers reporting an increase (20%), decrease (43%) and no change (37%) in BTSCC. Researchers who have measured these milk parameters have reported a variety of change with AMS. Tousova et al. (2014) documented an increase in milk fat and protein content, but a decrease in BTSCC with the use of AMS with their Czech Fleckvieh cows. Milk fat and protein percentage levels were similar to our study, while BTSCC was lower at 164,000 cells/mL (Tousova et al., 2014). In an experiment done in Israel, cows milked in AMS had lower fat content and BTSCC than those milked conventionally, with no difference in milk protein (Shoshani and Chaffer, 2002). Similar to the current study, SCC, milk fat and protein content did not change after transitioning to AMS (Klungel et al., 2000; Svennersten-Sjaunja et al., 2000). In a Finnish study, milk fat content increased after the introduction of AMS from 3.9 to 4.2% while

BTSCC increased from 142,000 to 208,000 cells/mL, although the change in BTSCC was not significant (Salovuo et al., 2005). Rasmussen et al. (2002), Kruip et al. (2002), and de Koning et al. (2003) documented an increase in BTSCC, reporting average BTSCC between 193,000 and 302,000 cells/mL on AMS farms. Van der Vorst et al. (2002) showed that BTSCC on AMS farms in Denmark, Germany and The Netherlands initially increased during the first 1 to 2 yr of introducing AMS (BTSCC of 202,000 to 312,000 cells/mL) but improved after some time (191,000 to 277,000 cells/mL). The median time since farms transitioned to AMS in our study was > 2 years (Chapter 2), which may explain the low geometric mean BTSCC. Additionally, studies reporting an increase in BTSCC were all conducted more than a decade ago, and AMS have been improved since (Tremblay et al., in press). It is therefore possible that problems reported in the earlier days of AMS implementation have been largely resolved.

Milking frequency and the difference in time spent on milking-related activities were larger for the Lely brand versus DeLaval, while milk fat content was greater for DeLaval versus Lely. There were no brand differences in average herd size or number of cows/robot, and there were significantly more free flow robots of both brands than there were directed traffic robots (Chapter 2), so differences in milking frequency and time devoted to milking-related activities cannot be the result of these 2 variables. To our knowledge, there is no literature that addresses specific brand differences in any of these variables or provides explanations for differences between brands of AMS.

With the large amount of data generated by an AMS on farm, producers using this technology may decide to cease participation in a DHI program (Barkema et al., 2015). The proportion of herds in Canada enrolled in an official (recognized) DHI program decreased from 43.1 to 42.7% from 2014 to 2015 (Canadian Dairy Information Centre, 2016). In the same year,

the proportion of dairy farms in Canada that used AMS increased from 5.6 to 6.8% (Canadian Dairy Information Centre, 2016). It is not possible to determine if this decrease in participation in DHI programs was an immediate result of farms transitioning to AMS, as herd-types (AMS or otherwise) were not specified. In our study, 11 (50%) of 22 AMS respondents, who were not DHI participants, had left DHI as a result of adopting AMS. Moving forward it will be important for DHI organizations to find ways to make their programs attractive to AMS users; losing AMS farms in DHI programs may compromise their effectiveness in making national evaluations of dairy cattle and milk quality.

Survey limitations have been described previously (Chapter 2). In general, the main issues were the potential for misinterpretation of questions, recall bias, social desirability bias, and post-product rationalization (a bias that causes a purchaser of an expensive product to see through product faults as a way to justify their purchase; Cohen and Goldberg, 1970). Additionally, changes in housing and management that occurred at the same time as the transition to AMS (Chapter 2) may have influenced differences after the installation of AMS.

3.6 Conclusions

Farms using an AMS have reported an increase in milk yield with little effect on milk quality, and a decrease in the number of employees and time devoted to milking-related activities after the transition to AMS. Findings from this study can act as a benchmark for future Canadian dairy producers who decide to switch to AMS and aid in more successful transitions by providing information on what to expect with the change.

Table 3.1: Number of employees and time spent on milking related activities (means ± SE) of farms before and after transition to automatic milking systems by herd size.

	Herd Size (number of lactating cows)				Overall
	≤ 58 (n = 54)	59 – 85 (n = 55)	86 – 116 (n = 51)	≥ 117 (n = 51)	
Mean number of employees					
Prior to AMS	1.8 ± 0.2^a	2.2 ± 0.2^a	2.7 ± 0.3^{ab}	3.4 ± 0.4^b	2.5 ± 0.1
Current	1.4 ± 0.2^a	1.8 ± 0.2^a	2.2 ± 0.3^{ab}	2.6 ± 0.3^b	$2.0 \pm 0.1^*$
Mean time spent on milking-related activities (h/d)					
Prior to AMS	4.1 ± 0.3^a	4.4 ± 0.2^{ac}	5.6 ± 0.3^{bc}	7.0 ± 0.6^b	5.2 ± 0.2
Current	1.4 ± 0.1^a	1.7 ± 0.2^{ab}	2.1 ± 0.2^b	3.0 ± 0.3^c	$2.0 \pm 0.1^*$

[a,b] Means within a row without a common superscript are significantly different ($P < 0.05$).

[*] Different from overall value prior to AMS ($P < 0.001$).

Table 3.2: Distribution of milking variables by automatic milking system brand.

	Brand		Overall[1]
	Lely	DeLaval	
Median milkings/d/herd	3.0[a]	2.8[b]	3.0
1st – 3rd quartile	2.9 – 3.2	2.7 – 3.0	2.8 – 3.2
Respondents (n)	164	44	212
Robot occupation rate (% of day; mean $\pm$ SE)	78 $\pm$ 2	75 $\pm$ 3	77 $\pm$ 1
Respondents (n)	40	18	61
Median number of times cows are fetched/d	2[a]	2[a]	2
1st – 3rd quartile	2 – 2	2 – 3	2 – 3
Respondents (n)	43	22	69
Median number of fetched cows/robot	3[a]	4[a]	3
1st – 3rd quartile	2 – 4	2 – 5	2 – 5
Respondents (n)	42	22	68
Median failed (incomplete) milkings/robot	2.5[a]	2.5[a]	2.5
1st – 3rd quartile	1.0 – 3.0	1.6 – 2.9	1.2 – 3.0
Respondents (n)	41	22	64

[1] Overall values include respondents with all brands of AMS.

[a,b] Medians and means within a row without a common superscript are significantly different ($P <$ 0.05).

Table 3.3: Percentage of producers reporting change in milk yield and milk quality after transitioning to AMS, organized by months since transition to AMS.

Time since Transition[1]	Reported Change (% respondents)			Respondents (n)
	Increased	Decreased	Stayed the Same	
Milk yield				
≤ 24 mo	79	6	15	87
> 24 mo	83	3	14	118
Overall mean[2]	81	4	14	205
Bulk tank SCC				
≤ 24 mo	24	41	35	86
> 24 mo	16	45	39	116
Overall mean	20	43	37	202
Milk fat				
≤ 24 mo	22	13	65	23
> 24 mo	36	14	50	42
Overall mean	29	15	56	681
Milk protein				
≤ 24 mo	4	9	87	23
> 24 mo	15	7	78	41
Overall mean	12	9	79	671

[1] Distributions of perceived change for each item did not differ by time since transition.

[2] Overall mean includes three respondents that did not provide information on time since transition.

Table 3.4: Percentage of producers who reported change in milk yield and milk quality after transitioning to AMS, by brand and overall across all brands.

	Brand		Overall[1]
	Lely	DeLaval	
Milk yield[2]			
Increased (%)	85	65	82
Decreased (%)	3	9	4
Stayed the same (%)	11	26	14
Respondents (n)	158	43	205
Bulk tank SCC[3]			
Increased (%)	17	23	20
Decreased (%)	43	47	43
Stayed the same (%)	39	30	37
Respondents (n)	155	43	202
Milk fat[2]			
Increased (%)	17	55	29
Decreased (%)	21	0	15
Stayed the same (%)	62	45	56
Respondents (n)	42	22	68
Milk protein[3]			
Increased (%)	10	5	9
Decreased (%)	10	10	12
Stayed the same (%)	81	86	79
Respondents (n)	42	21	67

[1] Overall means include respondents with all brands of AMS.
[2] Distribution of reported change by brand were different ($P < 0.05$).
[3] Distributions of reported change were not different by brand.

Table 3.5: Differences between brand of AMS in milk production and milk quality.

	Brand		
	Lely	DeLaval	Overall[1]
Mean $\pm$ SE milk yield (kg/cow/d)	32.6 ± 0.3^a	32.3 ± 0.5^a	32.6 ± 0.3
Respondents (n)	157	45	206
Geometric mean SCC[2] (x1000 cells/mL)	180^a	180^a	180
$1^{st} - 3^{rd}$ quantile	150 – 216	145 – 200	150 – 209
Respondents (n)	144	35	182
Median % milk fat	3.9^a	4.0^b	4.0
$1^{st} - 3^{rd}$ quantile	3.8 – 4.0	3.9 – 4.2	3.8 – 4.1
Respondents (n)	43	22	69
Median % milk protein	3.3^a	3.3^a	3.3
$1^{st} - 3^{rd}$ quantile	3.2 – 3.4	3.2 – 3.3	3.2 – 3.4
Respondents (n)	42	22	68

[1] Overall values include respondents with all brands of AMS.

[2] Back-transformed log of bulk tank SCC.

[a,b] Medians and means within a row without a common superscript are significantly different (P < 0.05).

Chapter Four: **Producer Experience with Transitioning to Automatic Milking: Cow Training, Challenges, and Impact on Quality of Life**

4.1 Abstract

Despite the growing popularity of automatic milking systems (AMS), or milking robots, in Canada, there is little documentation of how Canadian dairy producers experience the transition to this milking technology. The objective of this national study was to document the experiences of Canadian dairy producers during the transition to and use of AMS. This paper reports on producers experiences with cow training, challenges during the transition and their solutions, and impact of the AMS on quality of life. AMS producers (n = 217) were surveyed from 8 Canadian provinces. Overall, producers experienced a positive transition to AMS. Producers perceived that AMS improved profitability, quality of their lives and their cows' lives, and had met expectations, despite experiencing some challenges during transition such as learning to use the technology and data, cow training, demanding first few days, and changing health management. Less than half of the AMS producers (42%) trained cows or heifers to use the AMS before the first milking with the robot. For those who implemented training, it took an average of 1 wk to train a cow or heifer to use the AMS. It took a median of 30 d for an entire herd to adapt to the AMS, whether or not cow training took place. On average, 2% of a herd was culled for not adapting, or not voluntarily milking, when otherwise physically and behaviourally normal. With AMS, producers gained more time flexibility, found work to be less stressful and physically demanding, found employee management easier, and improved herd health and management. The vast majority (86%) of producers would recommend transitioning to AMS.

59

4.2 Introduction

In Europe, the United States, Australia, and New Zealand, automatic milking systems (**AMS**), or milking robots, have had a positive effect on the quality of producers' lives (Reinemann and Smith, 2000; Bergman and Rabinowicz, 2013; Molfino et al., 2014; Woodford et al., 2015). When operating optimally, AMS have many benefits: improved cow health, easier health detection (Chapter 2), increased milk production (Chapter 3), more interesting/less routine activities (Woodford et al., 2015), needing less labour (Hansen, 2015), and a more flexible lifestyle (de Koning, 2010). Many of these benefits may only become apparent after a transitional period. This transitional period has yet to be documented in detail in Canada.

Training is an important aspect of transitioning to AMS and involves exposing the animal to the sounds and mechanical movements of the AMS prior to first milking (Jago and Kerrisk, 2011). Introducing heifers to the AMS prior to calving had a positive impact on milking intervals, frequency of feeding, and milk production after calving (Widegren, 2014). AMS companies recommend following a cow-training program to help with the transition to and use of AMS. However, the programs are not standardized, often differing in method, duration and specificity, and little is known about whether or not producers invest time in cow training or what methods they use.

During the transition to AMS, producers experience many changes (e.g., building modifications and cow health management; Chapter 2), some of which are more challenging than others. This technology is growing in popularity in Canada: the proportion of Canadian dairy farms that use AMS grew from 5.6% in 2014 to 6.8% in 2015 (Canadian Dairy Information Centre, 2016). Still, there is limited documentation of how producers experience the transition and how AMS has impacted the quality of Canadian dairy producers' lives. The objective of this

study was, therefore, to describe how Canadian dairy producers experience the transition to and use of AMS, focusing on experiences with cow training, challenges during the transition, and impact on their quality of life.

4.3 Materials and Methods

This research was part of a larger study aimed at determining the impact of transitioning to AMS on producers' perceptions of change in farm management and cow health in the Canadian dairy industry. Methodology of the study is presented in detail in Chapter 2. Institutional human ethics certification was received prior to contacting participants (University of Calgary, certification no. REB14-0149_MOD1). Consent was received prior to each survey and surveys that were terminated before completion were excluded from the study.

4.3.1 Farm Selection and Data Collection

In short, provincial milk boards (Alberta Milk, Edmonton, AB, Canada, and Dairy Farmers of Manitoba, Winnipeg, MB, Canada), Lely Canada (Woodstock, ON, Canada) and DeLaval Canada (Peterborough, ON, Canada) provided access to producers who were using AMS in the country. Producers' contact information was compiled to make our sampling frame. All producers in our sampling frame were contacted and data were collected on those willing to participate. Surveys were conducted from May 2014 to the end of June 2015. AMS farms were surveyed in British Columbia (**BC**; n = 8), Alberta (**AB**; n = 43), Saskatchewan (**SK**; n = 7), Manitoba (**MB**; n = 12), Ontario (**ON**; n = 73), Quebec (**QC**; n = 66), New Brunswick, and Nova Scotia by telephone, email and in person. New Brunswick and Nova Scotia were referred to collectively as the 'Maritimes' (n = 7). Producers were initially contacted by phone with the

61

General Survey and, those who were interested, were emailed a link with follow-up questions. Producers who could not be reached by phone were emailed a link to the Combined Survey, which contained the General Survey and follow-up questions.

4.3.2 Surveys

The General Survey included questions about changes to housing, milk production, milk quality, milking labour management, AMS milking statistics, experience with cow training, challenges and solutions experienced during the transition, changes in quality of life, and overall level of satisfaction with AMS. The Combined Survey contained all questions from the General Survey, as well as more in-depth questions on topics covered in the General Survey, and questions related to cow health and participation in a dairy herd improvement program. The follow-up to the initial survey consisted of questions exclusive to the Combined Survey. Sample size varied per question since respondents had the option to skip questions. There were 217 respondents for General Survey questions, and 69 respondents for the follow-up questions, which were specific to the Combined Survey.

4.3.3 Statistical Analyses

Statistical analyses were performed with R (version 3.2.2; The R Foundation for Statistical Computing Platform, 2015). A P-value < 0.05 was considered statistically significant. Data analysis primarily included descriptive statistics (means, SE, medians, 1st – 3rd quartiles, percentages). Results with normal distribution are presented as means $\pm$ SE, and results with non-normal distribution are presented as medians with 1st – 3rd quartiles (**IQR**). Since producers

were given the option to skip to questions without providing an answer, sample sizes were calcuated as the number of respondents per question.

Brand comparisons were only made between Lely (n = 165) and DeLaval (n = 45) due to the small sample sizes of Insentec (n = 2) and BouMatic (n = 2) users. Chi-square test or Fisher's exact test, for cases that involved frequency counts < 5, was used to compare categorical, frequency data (e.g., when comparing by brand the proportions of respondents who train cows, heifers, or both, to use AMS). ANOVA and Tukey's post-hoc procedure were used to compare group means for normally distributed variables (a two sample t-test was used when comparing means of two groups). Kruskal-Wallis test with Dunn's test post-hoc were used to compare ≥ 3 group medians of variables that were not normally distributed and Wilcoxon Rank Sum and Signed Rank test when comparing two medians.

Producers were asked to score four statements ("AMS has improved profitability", "AMS has improved quality of my life", "AMS has improved quatliy of my cows' lives", and "AMS has met expectations") on a scale from 1 (strongly disagree) to 5 (strongly agree). Kendall's tau was used to measure the strength of associations between the scores of each statement. Spearman's correlation coefficient was used to measure the strength of associations between scores and time since transition to AMS (inclusive of all respondents), herd size, and producer age group (< 35, 35 – 45, 46 – 56, > 56 yr).

Open-ended questions were analyzed with inductive, thematic analysis (Green and Thorogood, 2013). Responses for open-ended questions were coded for re-occurring themes or patterns, which were then quantified for the purpose of describing how common those themes were among our respondents (Green and Thorogood, 2013).

4.4 Results

4.4.1 Information Sources

In total, 217 producers were surveyed in 8 provinces across Canada. Complete demographic description of respondents can be found in Chapter 2. The most commonly used sources of information that producers consulted prior to adopting AMS were: the supplier of AMS, other farmers, individual farm visits (veterinarians or consultants), and technical farm magazines and newspapers (Table 4.1). Sources that producers reported as "Other" in Table 4.1 included traveling to Europe to visit AMS farms and searches on the Internet. The least consulted information sources were TV or radio programs, blogs and podcasts. Overall, 93% of producers were satisfied with the level of support received from their preferred sources of information. Median level of satisfaction with the support provided by the professional advisors like veterinarians, consultants and specialists (56 respondents) was 4 (IQR: 3 – 4) on a scale of 1 (very dissatisfied) to 5 (very satisfied).

4.4.2 Cow Training

Overall, 42% of producers trained either cows or heifers (Table 4.2). Eighteen percent of AMS farms trained heifers before calving, with no differences by brand ($P = 0.35$). Nearly all producers (99%) supervise a cow's first milking with AMS. Small training groups of < 20 cows were more common (63% of respondents) than group sizes of ≥ 20 (37%). On average, farms that trained cows to use AMS (n = 42 respondents) required cows to visit the AMS a median of 2 times/d (IQR: 2 – 3 times/d) during the first and second week of training, with no differences by brand of AMS. Producers often provided feed in the AMS during training of cows and heifers, but were less likely to have the robot arm spray teats with disinfectant (to create awareness of the

64

arm) as part of cow and heifer training (Table 4.2). The majority of producers (60%) allowed cows to be more than 6 h late before fetching them during the first 2 wk of training.

For producers who used a training program, it took a median of 7 d to train a cow or heifer (Table 4.2). Comparatively, producers who did not train cows or heifers before first milking with the AMS believed that it would take 7 d (IQR: 3 – 10 d) to train cows and 7 d (IQR: 5 – 10 d) to train heifers. It was estimated for an entire herd a median of 30 d (IQR: 14 – 76 d) to adapt to the AMS. The number of days it took for an entire herd to adapt to the AMS did not differ if training of cows and/or heifers had or had not occurred ($P \geq 0.30$). There were no brand differences in the number of days for a herd to adapt ($P = 0.61$). The median proportion of a herd culled for not adapting (i.e., for not voluntarily milking while otherwise normal in appearance and behaviour) was 2%, with a range of 0 to 40%. There were no brand differences in proportion of a herd culled for not adapting (Table 4.2).

4.4.3 Challenges and their Solutions during Transition

AMS producers encountered a wide variety of challenges when transitioning to and using AMS (Table 4.3). Some of the main challenges producers experienced during transition included: learning to use the AMS (some found the technology "complicated" and felt overwhelmed with the amount of data it produced); cow training (breaking the cows' routine and difficulty training heifers and old cows); issues with nutrition (balancing feed and the cost of feed); trusting the AMS and changing mindset (accepting that the farm requires a different style of management and is now more computer-reliant, and having to change their own routines); having an extremely demanding first few days/weeks at start up (needing to recruit extra help or not having enough help, requiring an intense amount of physical labour to push cows through the

AMS, and trying to keep employees motivated); and having to change health management (to deal with feet/leg, heat detection, reproduction and mastitis issues, and to manage cow health more on an individual animal basis). Other challenges that were experienced by a very small number of producers (1 to 2 respondents/challenge) included general maintenance for the AMS, having little knowledge about cows as a first time dairy owner, managing cow traffic to the AMS, making too much milk, needing more robots at start-up, and simply not enjoying the technology. Common solutions to most of the listed challenges in Table 4.3 were time and patience, to be proactive, and to be willing to ask for help from others (e.g., dealer, other AMS farmers, nutritionists, etc.).

4.4.4 Quality of Life

Overall, producers scored all improvement and expectation statements positively (median scores of 4 or 5 on the scale of 1 to 5), indicating a high level of satisfaction (Table 4.4). Lely users more strongly agreed that their AMS had improved their quality of life, and more strongly agreed that their AMS had met expectations, when compared to DeLaval users (Table 4.4).

There was a negative correlation between scores given to "AMS has met expectations" and time since transition ($r_s = -0.16$, $P = 0.02$). There were also a negative correlation between herd size and scores given to "AMS has improved quality of my life" ($r_s = -0.17$, $P = 0.01$) and "AMS has met expectations" ($r_s = -0.15$, $P = 0.03$). There were no differences between improvement and expectation scores and the producers' age groups ($P \geq 0.17$). There was a positive correlation between every comparison of the 4 improvement and expectation statements (Table 4.5).

The most commonly reported improvements to quality of life since transitioning to AMS were increased flexibility with time (97% of producers), work being less stressful and less physically demanding on their body (37%), easier employee management (14%), and indirectly through improved herd health and better herd management (11%). Some producers elaborated that they can now spend more time with their families, attend meetings, get more sleep, and have time for other farm chores and crop duties. With less physical work required, a few producers noted an improvement in their health, as they previously experienced neck and back issues when milking with the parlour. Employee management was described as being easier with AMS because of several reasons: some producers no longer have any employees to deal with or have fewer employees; not needing to rely on employees as much with robotic milking; and being able to hire and train employees with limited cattle experience relatively quickly, if the producer would like to or needs to go away for a while. Other improvements to quality of life included greater job satisfaction and better work conditions, increased production, profit and efficiency, and lastly, having greater involvement of and interest from the younger generation.

Median score for annual workload after switching to AMS (on a scale of 1 – very small workload, to 5 – very heavy workload) was 3 (IQR: 2 – 3). There was no difference between brands of AMS ($P = 0.73$). Switching to AMS was only part of a farm succession plan or strategy for 46% of producers, with no differences by brand ($P = 0.29$).

Most surveyed producers (86%) would recommend transitioning to AMS to other farmers. Only 1% would not recommend AMS to other producers and 13% stated the recommendation would depend on whom they were recommending the technology to, as some farmers are "less tech-savvy". Proportions of producer recommendations did not differ by brand ($P \geq 0.36$).

4.5 Discussion

This is the first study to provide detailed information about how Canadian dairy producers experience the transition to AMS, and first to comprehensively describe experiences with cow training, challenges during the transition (and their solutions), and impact on quality of life. Producers experienced a positive transition to AMS and would recommend AMS to other dairy producers. Less than half of the AMS producers trained cows or heifers to use the AMS before the animal's first milking with the robot. Despite some challenges, producers perceived that AMS improved profitability, quality of life and their cows' lives, and had met expectations.

Similar to the current study, in Sweden the top 3 information sources used for making the adoption decision were other producers, supplier of AMS, and advisors (Bergman and Rabinowicz, 2013). Interestingly, unlike the Canadian producers surveyed in our study, the Swedish producers in the Bergman and Rabinowicz (2013) study were not satisfied with the level of support provided by the advisors and believed that the advisors were not knowledgeable enough about AMS.

AMS companies often recommend a training program to help cows adapt to the AMS. Training usually entails bringing cows to the AMS unit from 1 to 4 times/d (without milking, but providing high concentrate feed) for 3 to 14 d before start-up (DeLaval International AB, 2008; Hulsen and Rodenburg, 2008). Producers who trained cows used group sizes that were smaller than the recommended training group size of 25 to 30 cows (Hulsen and Rodenburg, 2008). Our study showed that producers took 1wk to train cows or heifers to adapt to the AMS. Other studies that trained (Jacobs and Siegford, 2012b) or did not train (Spolders et al., 2004) cows,

reported a similar average of 7 to 8 d for a cow to adapt to an AMS. The average time for an entire herd to adapt was 30 days, similar to what has been suggested by Rodenburg (2002).

A study conducted in Ontario, Canada documented that producers culled an average of 0 to 3% more cows with AMS due to close teat placements, unusual udder conformation that made it difficult for the robot to scan for teats, and "lazy" cows that involuntarily attended milkings when otherwise normal in appearance and behaviour (Rodenburg, 2002). In the current study, the proportion of a herd culled exclusively due to "laziness", as defined by Rodenburg (2002), fell within the higher end of this range, which suggests that culling cows in AMS due to poor teat placement and udder conformation was less common than culling lazy cows. It was speculated that despite the reported benefits of providing exposure to the AMS prior to first milking (e.g., fewer fetch cows, positive impact on milking intervals and milk production; Jago and Kerrisk, 2011; Widegren, 2014), surveyed producers might have chosen not to train cows to use the AMS because of the extra time and effort needed to do so.

The negative correlation between the statement "AMS has met expectations" and time since transition to AMS, which implied that satisfaction with AMS decreased with time, is understandable as older AMS units may start to require more maintenance or since newer models of AMS may have improved and have less problems than older versions. It could also be that producers with more recently installed AMS units were under the influence of post-product rationalization, which occurs when a purchaser of an expensive product sees through product faults as a way to justify their purchase (Cohen and Goldberg, 1970). Rather than interpreting the older AMS farms as being less satisfied, it could be viewed that this bias influenced a higher score for meeting expectations in younger AMS farms.

Two other correlations showed that quality of producers' lives improved to a lesser extent on AMS farms with larger herd sizes, and that expectations with AMS were also met to a lesser extent on AMS farms with larger herd sizes. There were no differences in herd size between producers who experienced an increase, decrease or no change in milk yield or in bulk tank SCC (Chapter 3), so the associations cannot be due to reduced milk production or quality. It was speculated that producers with larger herds would not score the statement "AMS has improved quality of my life" as positively as producers with smaller farms since larger farms would not be able to decrease the number of employees (i.e., employee management) to the same extent as smaller farms. However, there was no association between the change in herd size and change in number of employees with the transition to AMS (Chapter 3). Further research is required to fully understand the extent of these relationships and the possible causes for their negative associations.

Challenges experienced by the producers were diverse, but not unusual. Being on-call and feeling overwhelmed by the amount of information the AMS produced were challenges that have been experienced by other producers (e.g. Hansen, 2015). Changing practices and having less contact with cows were challenges that took time for producers to get used to. For some producers, physical contact with their cows plays a big role in job satisfaction (Meskens et al., 2001). Among Swedish producers, having reduced contact with cows was an important reason for not installing AMS (Bergman and Rabinowicz, 2013).

As shown in the solutions expressed by producers in our study, and as documented by Hansen (2015), it is clear that experiences and opinions of other AMS farmers (local and international) are important to producers who are considering or in the process of transitioning to AMS. As such, it may be beneficial to implement an international, online, producer-based, AMS

forum so knowledge can flow (more easily) between farmers. Furthermore, producers can make the transition easier by planning ahead in detail (e.g., finding a good contractor for renovations or building a new facility, and recruiting friends or hired-hands to help push cows through the robot the first few days), anticipating challenges that might not be a direct result of AMS (e.g., feet and leg issues when switching from tie-stall to free-stall housing), and opening the lines of communication and building a positive relationship with veterinarians, nutritionists, and the local AMS dealer so that a network of professionals is available to help with changes in cow health and technical issues with the AMS.

Animal welfare, as defined by Fraser (2009), encompasses 3 objectives: 1) to ensure good physiological health of animals, 2) to minimize unpleasant affective states such as pain, fear and distress, and 3) to allow animals to live in a way that is natural for the species (i.e., to allow expression of innate behaviours). With the limitations of the survey questions, the current study can only indicate impacts of AMS on perceptions of quality of the animals' lives and on the physiological aspects of animal welfare. Cow welfare improved with the transition to AMS, as indicated by producers' scores given to the statement "AMS has improved quality of my cows' lives". This study has also documented that welfare improved with AMS because of improved detection of health issues (Chapter 2). Other studies have documented improvements to cow welfare in terms of this technology providing cows more control over their daily time budget (Driessen and Heutinck, 2015; Lind et al., 2000), better cow health and increased production (Woodford et al., 2014; Hansen, 2015), and improved cow comfort (de Koning, 2010).

Overall, transitioning to AMS had a positive effect on the quality of producers' lives. Improvements to producers' lives with the transition to AMS were very similar to what other

studies have documented abroad (e.g., in Australia, New Zealand and Norway): more flexible working hours, which improved producers' family and social life (Molfino et al., 2014); improved health of producers with the reduced physical workload (see review by Meskens et al., 2001); as well as increased job satisfaction on AMS farms in New Zealand and Norway (Woodford et al., 2014; Hansen, 2015). Producers in the current study, like those in Australia (Molfino et al., 2014), felt their expectations around AMS were met, and like producers in Sweden (Bergman and Rabinowicz, 2013), would recommend transitioning to this new technology to others. Despite that the existence of a farm successor has shown to increase the probability of investing in an AMS, less than half of our AMS respondents switched as part of a farm succession plan.

Limitations have been described previously for this study (Chapter 2). In general, the main issues were the same as for all surveys: potential for misinterpretation of questions, recall bias, social desirability bias, and post-product rationalization.

4.6 Conclusions

Overall, producers experienced a positive transition to AMS and the majority of producers would recommend this technology to others. Our findings benchmark the experiences of Canadian dairy producers during the transition to and use of AMS, which will help producers make a more informed decision about adopting AMS and will make future transitions easier by detailing what should be expected of the change.

Table 4.1: Sources of information Canadian dairy producers consulted with prior to adopting AMS (respondents chose > 1 preferred information source; n = 78 respondents).

	Respondents	
Information Sources	No.	%
Supplier of AMS ("Dealer")	58	74
Other farmers	57	73
Individual farm visits (veterinarians, consultants)	21	27
Technical farm magazines and newspapers	21	27
On-farm demonstrations/workshops	16	21
Local/regional meetings (educational or industrial)	11	14
Other	8	10
Instructional videos and DVDs	5	6
Research papers or university extension fact sheets	3	4
Newsletters	2	3
Webinars	2	3
TV or radio programs	1	1
Blogs	1	1
Podcasts	0	0
None of the above	0	0

Table 4.2: Training practices used by AMS producers.

Item	Brand[1]		Overall[2]
	Lely	DeLaval	
Respondents who…[3] (%)			
Train cows only	6	4	6
Train heifers only	21	29	22
Train both cows and heifers	13	16	14
Do not train at all	59	51	58
Respondents (n)	165	45	214
Provide feed during training (%)			
Cows	92[a]	86[a]	88
(respondents, n)	(25)	(14)	(42)
Heifers	92[a]	85[a]	90
(respondents, n)	(25)	(13)	(40)
Spray teats during training (%)			
Cows	55[a]	31[a]	47
(respondents, n)	(22)	(13)	(38)
Heifers	45[a]	38[a]	45
(respondents, n)	(25)	(13)	(38)
Median (IQR, no. respondents) days to train			
Cows[4]	7	5	7
	$(3-10, 30)$	$(3-11, 7)$	$(3-10, 38)$
Heifers	6[a]	7[a]	7
	$(3-9, 55)$	$(4-7, 17)$	$(3-9, 73)$
Median proportion of herd culled	1%[a]	3%[a]	2%
(IQR, no. respondents)	$(0-3\%, 97)$	$(2-5\%, 31)$	$(1-3\%, 130)$

[1] Only Lely and DeLaval were tested for differences (where sample sizes were > 10) due to small sample sizes of other brands.
[2] Overall values include other brands (Insentec, BouMatic) and anonymous respondents.
[3] There were no differences in distribution of respondents by brand.
[4] Item was not tested for brand differences due to small sample sizes.
[a,b] Medians and proportions within a row without a common superscript are significantly different ($P < 0.05$).

Table 4.3: Challenges experienced by producers (n = 201) during the transition to and use of AMS and respective solutions.

Challenge (No. respondents with that challenge)[1]	Solutions (No. respondents with those solutions)
Learning to use the AMS (n = 68)	Time and patience (42), getting help from the dealer (10), trial and error (8), get help from younger generation (4), talking to other AMS producers (2), attend seminars (1)[2]
Cow training (n = 51)	Time and patience (28), creating small groups for training (5), recruiting extra help for the training period (4), suggests others to implement training programs (3), culling/selling cows that could not learn (1)[2]
Feed balance and nutrition (n = 31)	Working with a nutritionist or feed consultant (18), trial and error (6), switching feed companies (4), being a better observer (3), talking to other AMS farmers (in Canada and abroad) (2)
Trusting the AMS and changing mindset (n = 30)	Time and patience (23), trusting what the dealers had to say (3)[2]
Demanding first few days/weeks (n = 30)	Time, patience and effort (15), recruiting extra help (10), focussing on working efficiently (1), educating and encouraging employees (1), suggests transitioning in March vs. May in order for the transition to be done before field work season (1)[2]
Changing health management (n = 21)	Feet and leg: trim and check hooves often (be proactive) (7), implement use of footbath (3) Heat detection: be a better observer (2), use activity monitor (2) Reproduction: implement new observation system (2), learn to plan ahead (1) Mastitis: be more vigilant and proactive (2)
Non-AMS transition issues caused by converting from tie stall to free stall (n = 20)	Time and patience to allow cows to adjust (14), some use force to get them to get up (3), install mats to prevent slipping (3), implement trimming schedule and use of footbath for feet/leg issues (2)
Building modifications (n = 17)	Time to plan it out well (8), effort to "just do it" (4), talking to other AMS farmers (2), help from dealer (1)[2]
Technical issues (n = 17)	Technical issue-specific solution (3), self taught to fix issues (2), help from dealer (2), talking to other AMS farmers (1), replacing the robot (1), preventative maintenance (1), trying not to get frustrated (1)[2]

Table 4.3: Continued.

Challenge (No. respondents with that challenge)	Solutions (No. respondents with those solutions)
Feet and leg issues (n = 16)	Implement more frequent trimming and use of footbath (preventative maintenance) (10), install non-slip mats (1), build pack pen for lame cows (1), changed diet (1)[2]
Being on call (n = 15)	Time to adjust and accept it (5), hire help (2), stay on top of maintenance (2), do better at checking and cleaning the AMS unit before bed (1)[2]
Poor service from dealer and lack of support from others (n = 14)	Learning to solve problems by oneself (4), talked to other farmers (2), switching dealers (1), making complaints noticed by dealer (1)[2]
Decreased milk quality (n = 9)	Changing management (e.g., routing cows differently within the barn so they can be examined easier and more frequently) (2), culling high SCC cows (1), giving it time as SCC returned to normal on its own (1), dealer fixed spray apparatus (1)[2]
Finances (n = 6)	Creating a budget (2), time and profit (2), being more efficient (1), re-financing the operation (1)
Employee management and training (n = 6)	Communicate and work patiently with employees (3), create an SOP (1)[2]

[1] Respondents were allowed to list more than one challenge (i.e., number of respondents for each challenge are not necessarily independent of one another).

[2] Some producers did not have a solution to this challenge.

Table 4.4: Average and median quality of life statement scores by brand and across all brands.

Item	Brand[1]		Overall[2]
	Lely	DeLaval	
Improved profitability			
Median (1st – 3rd quartile)	4[a] (3 – 5)	4[a] (3 – 4)	4 (3 – 5)
Mean $\pm$ SE	3.9 $\pm$ 0.1	3.5 $\pm$ 0.2	3.8 $\pm$ 0.1
Improved quality of producer's life			
Median (1st – 3rd quartile)	5[a] (4 – 5)	4[b] (4 – 5)	5 (4 – 5)
Mean $\pm$ SE	4.5 $\pm$ 0.1	4.3 $\pm$ 0.1	4.5 $\pm$ 0.1
Improved quality of cows' lives			
Median (1st – 3rd quartile)	5[a] (4 – 5)	5[a] (4 – 5)	5 (4 – 5)
Mean $\pm$ SE	4.5 $\pm$ 0.1	4.3 $\pm$ 0.1	4.5 $\pm$ 0.1
Met expectations			
Median (1st – 3rd quartile)	5[a] (4 – 5)	4[b] (4 – 5)	5 (4 – 5)
Mean $\pm$ SE	4.4 $\pm$ 0.1	4.2 $\pm$ 0.1	4.4 $\pm$ 0.1

[1] Only Lely and DeLaval were tested for differences (where sample sizes were > 10) due to small sample sizes of other brands.

[2] Overall values include other brands (Insentec, BouMatic) and anonymous respondents.

[a,b] Means within a row without a common superscript are significantly different ($P < 0.05$).

Table 4.5: Associations between producers' improvement and expectation statement scores (scored on a scale of 1-strongly disagree, to 5-strongly agree) using Kendall's tau (τ).

AMS has…	Improved profitability	Improved quality of my life	Improved quality of my cows' lives	Met expectations
Improved profitability	-	$\tau = 0.20$ $P = 0.001$	$\tau = 0.30$ $P < 0.001$	$\tau = 0.42$ $P < 0.001$
Improved quality of my life	-	-	$\tau = 0.32$ $P < 0.001$	$\tau = 0.33$ $P < 0.001$
Improved quality of my cows' lives	-	-	-	$\tau = 0.34$ $P < 0.001$
Met expectations	-	-	-	-

Chapter Five: **General Conclusions and Future Perspectives**

5.1 Summary of Work

The aim of this project was to explore how Canadian dairy producers transitioned to AMS. Overall, Canadian dairy producers perceived their transitions to AMS as successful. Changes to housing were necessary but cleaning and feeding practices stayed the same after installing AMS. Changes made to housing and management practices (within the limits of this survey) largely met industry standards. Farms were able to increase their herd size and increase milk yield, while decreasing the number of employees and time devoted to milking labour management. In another survey, farms increased herd size and decreased time devoted to milking labour management with AMS (Bentley et al., 2013). The reported increase in milk yield agrees with many other published studies (Wagner-Storch and Palmer, 2003; Hansen, 2015; Woodford et al., 2015). The average milk yield of AMS farms in this study, 32 kg/cow/d, was typical for North American AMS dariy farms (Tremblay et al., 2016). A decrease in the number of employees with the transition to AMS has also been found in the Netherlands (Bijl et al., 2007).

There was little effect on milk quality: milk fat and protein levels were reported to stay the same, BTSCC either decreased or stayed the same, but total bacterial count varied in reported change. Experimental studies have shown a variety of change in BTSCC, milk fat, and milk protein with AMS (Klungel et al., 2000; Shoshani and Chaffer, 2002; Tousova et al., 2014). Unlike our results on perceived change in total bacterial count, most studies have documented increased bacterial count with AMS (Klungel et al., 2000; Rasmussen et al., 2002; de Koning et al., 2003).

Producers needed to change health management practices with this technology, but the majority of producers found health detection easier. Improvement to health detection in AMS was a result of the vast amount of information provided, which has been reported by other studies (see review by Barkema et al., 2015). The perceptions of change in mastitis and lameness (which were reported to have decreased or stayed the same) and conception rate (which was reported to have increased) showed similarities to experimental studies on cow health in AMS (Hovinen et al. 2009; Kruip et al., 2002; Westin et al., 2016).

The DCOP was a source of reference for 20% of producers (results presented in Appendix 3). Producers believed that AMS positively impacted how well their farm now followed the requirements of the DCOP. A revised DCOP with improved relevance to AMS may increase the currently low use of the DCOP as a source of reference when making plans to adopt this technology.

Participation in DHI decreased with the transition to AMS among our respondents, although 67% were current participants. DHI programs must find ways to attract or maintain attractiveness to AMS users. Losing AMS farms in DHI programs may negatively affect their effectiveness in making national evaluations of dairy cattle and milk quality.

For producers who trained their animals, it took on average 7 d to train a cow or heifer. Studies have reported a similar average of 7 to 8 d for a cow to adapt to the AMS (Spolders et al., 2004; Jacobs and Siegford, 2012b). However, most producers in the current study did not train cows. Whether or not training occurred, it took an average of 30 d for an entire herd to adapt, which was similar to what Rodenburg (2002) had been previously documented.

Challenges experienced during the transition included learning to use the technology and data, cow training, demanding first few days, and changing health management. The list of all challenges was diverse but not unusual (see review by Meskens et al., 2001). Based on the most common solutions to the challenges, it may be beneficial to implement an international, online, producer-based, AMS forum so knowledge can flow more easily between farmers. Producers can also make the transition easier by planning in detail for the build/renovations and the labour-intensive start-up, anticipating challenges that might not be a direct result of AMS, and opening the lines of communication and building a relationship with veterinarians, nutritionists, and the local AMS dealer so that a network of professionals is available to help with changes in cow health and technical issues with the AMS.

Animal welfare (as defined in Chapter 1) had improved with the adoption of AMS in terms of perceptions of quality of the animals' lives and on the physiological aspects of animal welfare. When asked, producers reported that the quality of their cows' lives had improved and as a result of their animals being less stressed. This technology had also improved cow welfare by improving detection of health issues.

Overall, AMS had improved perceived profitability, quality of producers' lives, and met expectations. Improvements to producers' quality of life were similar to what other studies have documented: gaining more time flexibility, work being less stressful and physically demanding, easier employee management, as well as improving herd health and management (Meskens et al., 2001; Woodford et al., 2014; Hansen, 2015). The majority of producers would recommend transitioning to AMS to other dairy producers.

5.2 Limitations

Limitations to this survey were like what applies to most surveys. There was a potential for recall bias, misinterpretation of questions, interviewer bias, social desirability bias, and post-product rationalization. Recall bias is an issue of remembering accurately. This bias was minimized by letting producers skip questions if they could not accurately remember a particular detail of the transition. Misinterpretation of questions was reduced by first running a pilot study, determining which questions caused confusion and then making necessary changes. There was also an opportunity for interviewers to clarify questions during phone and in-person surveys. Risk for interviewer bias (during phone and in-person surveys) was minimized by asking questions strictly as they were written in the final version of the survey (which was the same as the online survey), and by only providing standardized prompts and clarifications when necessary. Social desirability bias is the tendency to respond differently in the presence of an interviewer so that one appears in favourable light (Green and Thorogood, 2013). Interviewers (students from Canadian universities) first introduced themselves before conducting phone and in-person surveys. It was made clear that the study was being conducted through the University of Calgary, independent of AMS companies. Informing the producers that the study was being conducted as part of a university project, and not in the interest of AMS companies, allowed producers to understand that they had nothing to gain or lose by giving their honest account of the transition. Producers may have been influenced by post-product rationalization, a cognitive bias through which a purchaser of an expensive product looks past any product faults as a way to justify their purchase (Cohen and Goldberg, 1970). This bias may have distorted results to show more improvements on farm since transitioning to AMS.

There may have been a bias created by the type of respondents who chose to participate in the survey. We could not collect data on those who did not want to participate, thus it is not known if those AMS producers experienced a different transition. As well, the results were bound by the limits of the survey questions that were asked. The survey was designed to address many aspects of farming in a fair amount of detail without compromising its completion by being too long. Alas, not every question that was thought up during the design of the survey could be included in the final version. Lastly, it should be noted that the possible differences after transitioning to AMS may not be a result of just the new milking system, but also of the changes in housing and management that accompanied the installation of the AMS.

5.3 Implications

This national survey is the first to document the impacts of transitioning to AMS on producer perceptions of change in important aspects of Canadian dairy farming in tandem with determining how producers experience the transition. Findings from this study provide a benchmark of impacts of AMS: housing changes were necessary, feeding and cleaning practices stayed the same, cow health and milk quality were maintained, time devoted to milking related activities decreased while herd size and milk production increased, producers' quality of life and animal welfare improved, participation in DHI decreased, and the DCOP had a limited role in the transition to AMS. Our findings also provide a benchmark of producer experiences during the transition (with specific regard to cow training and general challenges and solutions). This study can help producers make a more informed decision about adopting this technology and can act as

a transitioning tool by providing producers, AMS dealers, veterinarians, and dairy advisors, with more detailed knowledge on the expectations, challenges and solutions when switching to AMS.

5.4 Future Perspectives

Future studies may further validate that producer perceptions of change during the transition to AMS reflect reality by comparing DHI records and AMS-generated data with the perceived changes. Specific to this study, perceptions of change and other reported values can be compared with data collected on Alberta AMS farms by King et al. (in prep.). Further work could evaluate the effect of time during transition (e.g., 1 mo versus 6 mo versus 1 and 2 yrs after transition) on the aspects of dairy farming that were looked at in this thesis. The effects of time since transition to AMS would be clearer by conducting a study that follows farms during the transition. Ensuring that many aspects are assessed (e.g., cow health, milking labour management, milk production and quality, producers' quality of life, etc.) would provide an all-encompassing depiction of changes that should be expected at various points of transition.

This survey could serve as a model in other countries for assessing how farms are transitioning to AMS. It would be beneficial to collect a more representative sample of AMS producers by province/state, as well as collect a more representative sample of each AMS brand by province/state. Doing so would allow for stronger provincial/state and brand comparisons of the impacts of transitioning AMS. Studies could further evaluate AMS brand differences in various aspects of transitioning and determine why, if any, differences exist.

References

Alberta Milk. 2014. Ask a Dairy Farmer – Policies. Accessed July 27, 2015. www.albertamilk.com.

Armstrong, D. V. and L. S. Daugherty. 1997. Milking robots in large dairy farms. Comput. Electron. Agric. 17:123–128.

Bach, A., M. Dinarés, M. Devant, and X. Carré. 2007. Associations between lameness and production, feeding and milking attendance of Holstein cows milked with an automatic milking system. J. Dairy Res. 74:40–46.

Barkema, H. W., M. A. G. von Keyserlingk, J. P. Kastelic, T. J. G. M. Lam, C. Luby, J.-P. Roy, S. J. LeBlanc, G. P. Keefe, and D. F. Kelton. 2015. Invited review: Changes in the dairy industry affecting dairy cattle health and welfare. J. Dairy Sci. 98:7426-7445.

Barnes, M. A., R. E. Pearson, and A. J. Lukes-Wilson. 1990. Effects of milking frequency and selection for milk yield on productive efficiency of Holstein cows. J. Dairy Sci. 73:1603-1611.

Berglund, I., G. Pettersson, and K. Svennersten-Sjaunja. 2002. Automatic milking: Effects on somatic cell count and teat end-quality. Livest. Prod. Sci. 78:115–124.

Bergman, K. and E. Rabinowicz. 2013. Adoption of the automatic milking system by Swedish milk producers. AgriFoods Economics Centre. Accessed May 24, 2016. http://www.agrifood.se/Files/AgriFood_WP20137.pdf.

Bentley, J. A., L. F. Tranel, L. L. Timms, and K. Schulte. 2013. Automatic milking systems (AMS) - Producer surveys. Animal Industry Report: AS 659, ASL R2788.

Bernier-Dodier, P., L. Delbecchi, G. F. Wagner, B. G. Talbot, and P. Lacasse. 2010. Effect of milking frequency on lactation persistency and mammary gland remodeling in mid-lactation cows. J. Dairy Sci. 93:555–564.

Bewley, J. and R. Russell. 2010. reasons for slow adoption rates of precision dairy farming technologies: Evidence from a producer survey. In Proc. First North Am. Conf. on Precision Dairy Management, Toronto, ON, Canada.

Bijl, R., S. R. Kooistra, and H. Hogeveen. 2007. The profitability of automatic milking on Dutch dairy farms. J. Dairy Sci. 90:239–248.

Borderas, T. F., A. Fournier, J. Rushen, and A. M. B. de Passillé. 2008. Effect of lameness on dairy cows' visits to automatic milking systems. Can. J. Anim. Sci. 88:1–8.

Butler, D., L. Holloway, and C. Bear. 2012. The impact of technological change in dairy farming: Robotic milking systems and the changing role of the stockperson. R. Agric. Soc. Engl. 173:1–6.

Canadian Dairy Information Centre. 2015. Dairy facts and figures. Accessed July 27, 2015. www.dairyinfo.gc.ca.

Canadian Dairy Information Centre. 2016. Dairy facts and figures. Accessed May 27, 2016. www.dairyinfo.gc.ca.

CanWest DHI. 2016. DHI and robotic milking. Accessed May 2, 2016. www.canwestdhi.com.

Cohen, J. B. and M. E. Goldberg. 1970. Dissonance product evaluation. J. Mark. Res. 7:315–321.

de Koning, C. J. A. M. 2010. Automatic milking - Common practice on dairy farms. In Proc. First North Am. Conf. on Precision Dairy Management, Toronto, ON, Canada.

de Koning, C. J. A. M. and J. Rodenburg. 2004. Automatic milking: State of the art in Europe and North America. Pages 27-40 in Automatic milking - A better understanding. A. Meijering, H. Hogeveen, and C. J. A. M. De Koning, ed. Wageningen Academic Publishers, Wageningen, The Netherlands.

de Koning, K., B. Slaghuis, and Y. Van der Vorst. 2003. Robotic milking and milk quality: Effects on bacterial counts, somatic cell counts, freezing point and free fatty acids. Ital. J. Anim. Sci. 2:291–299.

DeLaval Canada. 2014. DeLaval VMS voluntary milking system - A higher level of automatic milking [Brochure]. Ontario, Canada: DeLaval Canada.

DeLaval International AB. 2008. Instruction book VMS best practices [Brochure]. Tumba, Sweden: DeLaval International AB.

Deming, J. A., R. Bergeron, K. E. Leslie, and T. J. DeVries. 2013. Associations of housing, management, milking activity, and standing and lying behavior of dairy cows milked in automatic systems. J. Dairy Sci. 96:344–351.

Devir, S., J. A. Renkema, R. B. M. Huirne, and A. H. Ipema. 1993. A new dairy control and management system in the automatic milking farm: Basic concepts and components. J. Dairy Sci. 76:3607-3616.

De Vliegher, S., H. Laevens, H. W. Barkema, G. Opsomer, T. Hemling, and A. de Kruif. 2003. Short-term effect of transition from conventional to automated milking on teat skin and teat end condition. J. Dairy Sci. 86:1646–52.

DeVries, T. J., A. J. Deming, J. Rodenburg, G. Seguin, K. E. Leslie, and H. W. Barkema. 2011. Association of standing and lying behavior patterns and incidence of intramammary infection in dariy cows milked with an automatic milking system. J. Dairy Sci. 94:3845–3855.

DeVries, T. J., S. Dufour, and D. T. Scholl. 2010. Relationship between feeding strategy, lying behavior patterns, and incidence of intramammary infection in dairy cows. J. Dairy Sci. 93:1987–1997.

Driessen, C. and L. F. M. Heutinck. 2015. Cows desiring to be milking? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms. Agric. Hum. Values. 32:3-20.

Elmoslemany, A. M., G. P. Keefe, I. R. Dohoo, and B. M. Jayarao. Risk factors for bacteriological quality of bulk tank milk in Prince Edward Island dairy herds. Part 1: Overall risk factors. J. Dairy Sci. 92: 2634-2643.

Erdman, R. A. and M. Varner. 1995. Fixed yield responses to increased milking frequency. J. Dairy Sci. 78:1199–1203.

European Dairy Association. 2015. Facts & figures. Accessed July 27, 2015. www.eda.euromilk.org.

Fraser, D. 2009. Assessing animal welfare: Different philosophies, different scientific approaches. Zoo Biol. 28:507-518.

Green, J. and N. Thorogood. 2013. Thematic content analysis. Pages 209-218 in Qualitative methods for health research. 3rd ed. Sage. Los Angeles, California.

Greenough, P. R., F. J., MacCallum, and A. D., Weaver. 1981. Lameness in Cattle. 2nd ed. John Wright and Sons. Bristol, United Kingdom.

Hansen, B. G. 2015. Robotic milking-farmer experiences and adoption rate in Jaeren, Norway. J. Rural Stud. 41:109-117.

Helgren, J. M. and D. J. Reinemann. 2006. Survey of milk quality on U.S. dairy farms utilizing automatic milking systems. Am. Soc. Agric. Biol. Eng. 49:551–556.

Hillerton, J. E., J. Dearing, J. Dale, J. J. Poelarends, F. Neijenhuis, O. C. Sampimon, J. D. H. M. Miltenburg, C. Fossing. 2004. Impact of automatic milking on animal health. Pages 125-134 in Automatic milking - A better understanding. A. Meijering, H. Hogeveen, and C. J. A. M. De Koning, ed. Wageningen Academic Publishers, Wageningen, The Netherlands.

Hillerton, J. E. and A. Winter. 1992. The effects of frequent milking on udder physiology and health. Pages 201-211 in Proc. British Mastitis Conf., Stoneleigh, UK.

Hovinen, M. and S. Pyörälä. 2011. Invited review: Udder health of dairy cows in automatic milking. J. Dairy Sci. 94:547–562.

Hovinen, M., M. D. Rasmussen, and S. Pyörälä. 2009. Udder health of cows changing from tie stalls or free stalls with conventional milking to free stalls with either conventional or automatic milking. J. Dairy Sci. 92:3696–3703.

Hulsen, J. and J. Rodenburg. 2008. Robotic milking [Brochure]. Roodbont Publishers, Zutphen, the Netherlands.

Jacobs, J. and J. Siegford. 2012a. Invited review: The impact of automatic milking systems on dairy cow management, behavior, health and welfare. J. Dairy Sci. 95:2227:2247.

Jacobs, J. and J. Siegford. 2012b. Lactating dairy cows adapt quickly to being milked by an automatic milking system. J. Dairy Sci. 95:1575–1584.

Jago, J. and K. Kerrisk. 2011. Training methods for introducing cows to a pasture-based automatic milking system. Appl. Anim. Behav. Sci. 131:79–85.

Klungel, G. H., B. A. Slaghuis, and H. Hogeveen. 2000. The effect of the introduction of automatic milking systems on milk quality. J. Dairy Sci. 83:1998–2003.

Knight, C. H. and R. J. Dewhurst. 1994. Once daily milking of dairy cows: Relationship between yield loss and cisternal milk storage. J. Dairy Sci. 61:441–449.

Kruip, T. A. M., H. Morice, M. Robert, and W. Ouweltjes. 2002. Robotic milking and its effect on fertility and cell counts. J. Dairy Sci. 85:2576–2581.

Kruip, T. A. M., J. Stefanowska, and W. Ouweltjes. 2000. Robot milking and effect on reproduction in dairy cows: a preliminary study. Anim. Reprod. Sci. 60-61:443-447.

Lely. 2010. Lely's free cow traffic. Accessed June 4, 2016. http://www.lely.com/uploads/original/documents/Brochures/Farming_tips/Free_Cow_Traffic/Vrij_koeverkeer_-_Brochure_-_EN.pdf

Lind, O., A. H. Ipema, C. de Koning, T. T. Mottram, and H. -J. Hermann. 2000. Automatic milking: Reality, challenges and opportunities. Pages 19-31 in Robotic Milking Proc. Int. Symp., Lelystad, the Netherlands.

Markey, C. 2013. Effect of cow traffic system on cow performance and AMS capacity. MSc Thesis. Swedish Univ. of Agricultural Sciences, Uppsala.

Mathijs, E. 2004. Socio-economics aspects of automatic milking. Pages 46-55 in Automatic milking - A better understanding. A. Meijering, H. Hogeveen, and C. J. A. M. De Koning, ed. Wageningen Academic Publishers, Wageningen, The Netherlands.

Melin, M., K. Svennersten-Sjaunja, and H. Wiktorsson. 2005. Feeding patterns and performance of cows in controlled cow traffic in automatic milking systems. J. Dairy Sci. 88:3913–3922.

Mellor, D. 2016. Updating animal welfare thinking: Moving beyond the "Five Freedoms" towards "A Life Worth Living". Animals. 6:1-20.

Meskens, L., M. Vandermersch, and E. Mathijs. 2001. Implication of the introduction of automatic milking on dairy farms. Deliverable D2 from EU project 'Implications of the introduction of automatic milking on dairy farms' (QLK5 2000-31006). Accessed May 4, 2016. http://www.automaticmilking.nl.

Migliorati, L., M. Speroni, S. Lolli, and F. Calza. 2005. Effect of concentrate feeding on milking frequency and milk yield in an automatic milking system. Ital. J. Anim. Sci. 4:221–223.

Miguel-Pacheco, G. G., J. Kaler, J. Remnant, L. Cheyne, C. Abbott, A. P. French, T. P. Pridmore, and J. N. Huxley. 2014. Behavioural changes in dairy cows with lameness in an automatic milking system. Appl. Anim. Behav. Sci. 150:1–8.

Molfino, J., K. Kerrisk, and S. C. García. 2014. Investigation into the labour and lifestyle impacts of automatic milking systems (AMS) on commercial farms in Australia. Pages 339-342 in Proc. 5th Australian Dairy Sci. Symp., Melbourne, Australia.

Mollenhorst, H., M. M. Hidayat, J. van den Broek, F. Neijenhuis, and H. Hogeveen. 2011. The relationship between milking interval and somatic cell count in automatic milking systems. J. Dairy Sci. 94:4531–7.

Moyes, K., L. Ma, T. K. McCoy, and R. R. Peters. 2014. A survey regarding the interest and concerns associated with transitioning from conventional to automated (robotic) milking systems for managers of small- to medium-sized dairy farms. Prof. Anim. Scientist. 30:418-422.

Munksgaard, L., J. Rushen, A. M. de Passillé, and C. C. Krohn. 2011. Forced versus free traffic in an automated milking system. Livest. Sci. 138:244-250.

National Farm Animal Care Council. 2009. Code of practice for the care and handling of dairy cattle. Accessed June 8, 2016. http://www.nfacc.ca/codes-of-practice/dairy-cattle/code.

Neijenhuis, F., H. Hogeveen, and K. de Koning. 2010. Automatic milking systems : A Dutch study on risk factors for udder health. In Proc. First North Am. Conf. on Precision Dairy Management, Toronto, ON, Canada.

Ontario Ministry of Agriculture, Food and Rural Affairs. 2010. Better breeding with automated milking systems. Accessed May 21, 2016. http://www.omafra.gov.on.ca/english/livestock/dairy/facts/betbreeding.htm.

Persson Waller, K., T. Westermark, T. Ekman, and K. Svennersten-Sjaunja. 2003. Milk leakage - An increased risk in automatic milking systems. J. Dairy Sci. 86:3488–3497.

Prescott, N. B., T. T. Mottram, and A. J. F. Webster. 1998. Relative motivations of dairy cows to be milked or fed in a Y-maze and an automatic milking system. Appl. Anim. Behav. Sci. 57:23–33.

Rasmussen, M. D., M. Bjerring, P. Justesen, and L. Jepsen. 2002. Milk quality on Danish farms with automatic milking systems. J. Dairy Sci. 85:2869–78.

Reinemann, D. J. and M. A. Davis. 2002. Milking performance and udder health of cows milked robotically and conventionally. In 2002 ASAE Annual Int. Meeting/CIGR XVth World Congress, Chicago, IL, USA.

Reinemann, D. J. and D. J. Smith. 2000. Evaluation of automatic milking systems for the United States. Pages 232-238 in Robotic Milking Proc. Int. Symp., Lelystad, the Netherlands.

Rodenburg, J. 2002. Robotic milkers: What, where…and how much!! ?? Pages 1 – 18 in Proc. Ohio Dairy Management Conf., Columbus, OH, USA.

Rodenburg, J. 2011. Designing feeding systems for robotic milking. In Proc. Tri-State Nutrition Conf., Fort Wayne, IN, USA.

Rodenburg, J. and H. House. 2007. Field observations on barn layout and design for robotic milking of dairy cows. In Proc. 6th Int. Dairy Housing Conf., Minneapolis, MN, USA.

Rodenburg, J., N. Vreeburg, B. Westerlaan, W. Veenstra, and J. Pitkaranta. 2010. Design criteria for the ideal robotic milking barn. In Proc. First North Am Conf. on Precision Dairy Management. Toronto, ON, Canada.Rotz, C. A., C. U. Coiner, and K. J. Soder. 2003. Automatic milking systems, farm size, and milk production. J. Dairy Sci. 86:4167–77.

Rousing, T., I. A. Jakobsen, J. Hindhede, I. C. Klaas, M. Bonde, and J. T. Sørensen. 2007. Evaluation of welfare indicator protocol for assessing animal welfare in AMS herds: Researcher, production advisor and veterinary practitioner opinion. Anim. Welf. 16:213–216.

Rushen, J., L. Munksgaard, P. G. Marnet, and A. M. de Passillé. 2001. Human contact and the effects of acute stress on cows at milking. Appl. Anim. Behav. Sci. 73:1-14.

Salovuo, H., P. Ronkainen, A. Heino, A. Suokannas, and E. -L. Ryhanen. 2005. Introduction of automatic milking system in Finland: Effect on milk quality. Agric. Food Sci. 14:346–353.

Shoshani, E. and M. Chaffer. 2002. Robotic milking: A report of a field trial in Israel. In Proc. First North Am Conf. on Precision Dairy Management. Toronto, ON, Canada.

Solano, L., H. W. Barkema, E. A. Pajor, S. Mason, S. J. LeBlanc, J. C. Zaffino Heyerhoff, C. G. R. Nash, D. B. Haley, E. Vasseur, D. Pellerin, J. Rushen, A. M. de Passillé, and K. Orsel. 2015. Prevalence of lameness and associated risk factors in Canadian Holstein-Friesian cows housed in freestall barns. J. Dairy Sci. 98:6978-6991.

Sonck, B. R. 1997. Labor research on automatic milking with a human-controlled cow traffic. Neth. J. Agric. Sci. 43:261–285.

Spolders, M., U. Meyer, G. Flachowsky, and M. Coenen. 2004. Differences between primiparous and multiparous cows in voluntary milking frequency in an automatic milking system. Ital. J. Anim. Sci. 3:167–175.

Stefanowska, J., M. Plavsic, A. H. Ipema, and M. M. Hendriks. 2000. The effect of omitted milking on the behaviour of cows in the context of cluster attachment failure during automatic milking. Appl. Anim. Behav. Sci. 67:277-291.

Svennersten-Sjaunja, K., I. Berglund, and G. Pettersson. 2000. The milking process in an automatic milking system, evaluation of milk yield, teat condition and udder health. Pages 277-288 in Robotic Milking Proc. Int. Symp., Lelystad, the Netherlands.

Tousova, R., J. Duchacek, L. Stadnik, M. Ptacek, and J. Beran. 2014. The comparison of milk production and quality in cows from conventional and automatic milking systems. J. Cent. Eur. Agric. 15:100–114.

Tremblay, M., J. P. Hess, B. M. Christenson, K. K. McIntyre, B. Smink, A. J. van der Kamp, L. G. de Jong, and D. Döpfer. 2016. Factors associated with increased milk production for automatic milking systems. J. Dairy Sci. 99: 3824-3837.

Tremblay, M., J. P. Hess, B. M. Christenson, K. K. McIntyre, B. Smink, A. J. van der Kamp, L. G. de Jong, and D. Döpfer. In press. Customized recommendations for production management clusters of North American automatic milking systems. J. Dairy Sci.

USDA-ERS. 2015. Dairy Data. Accessed July 27, 2015. http://www.ers.usda.gov/data-products/dairy-data.aspx.

USDA-NASS. 2013a. Milk production. USDA-NASS, Washington, DC, USA.

USDA-NASS. 2013b. Livestock – historical track records. USDA-NASS, Washington, DC, USA.

Valacta. 2015. Our services. Accessed May 2, 2016. www.valacta.com

van der Vorst, Y., K. Knappstein, and M. D. Rasmussen. 2002. Milk quality on farms with an automatic milking system - Effects of automatic milking on the quality of produced milk. Deliverable D2 from EU project 'Implications of the introduction of automatic milking on dairy farms' (QLK5 2000-31006). Accessed May 4, 2016. http://www.automaticmilking.nl.

van't Land, A., A. C. van Lenteren, E. van Schooten, C. Bouwmans, D. J. Gravesteyn, and P. Hink. 2000. Effects of husbandry systems on the efficiency and optimisation of robotic

milking performance and management. Pages 167-176 in Robotic Milking, Proc. Int. Symp., Lelystad, the Netherlands.

von Keyserlingk, M. A. G., J. Rushen, A. M. de Passillé, and D. M. Weary. 2009. Invited review: The welfare of dairy cattle- Key concepts and the role of science. J. Dairy Sci. 92:4101-4111.

Waage, S., S. A. Odegaard, A. Lund, S. Brattgjerd, and T. Røthe. 2001. Case-control study of risk factors for clinical mastitis in postpartum dairy heifers. J. Dairy Sci. 84:392–399.

Wade, K. M., M. A. P. M. van Asseldonk, P. B. M. Berentsen, W. Ouweltjes, and H. Hogeveen. 2004. Economic efficiency of automatic milking systems with specific emphasis on increases in milk production. Pages 63-68 in Automatic milking - A better understanding. A. Meijering, H. Hogeveen, and C. J. A. M. De Koning, ed. Wageningen Academic Publishers, Wageningen, The Netherlands.

Wagner-Storch, A. M. and R. W. Palmer. 2003. Feeding behavior, milking behavior, and milk yields of cows milked in a parlor versus an automatic milking system. J. Dairy Sci. 86:1494–502.

Webster, J. 2005. Animal Welfare: Limping Towards Eden. Blackwell, Oxford, UK.

Westin, R., A. Vaughan, A. M. de Passillé, T. J. DeVries, E. A. Pajor, D. Pellerin, J. M. Siegford, A. Witaifi, E. Vasseur, and J. Rushen. 2016. Cow and farm-level risk factors for lameness on dairy farms with automated milking systems. J. Dairy Sci. 99:3732–3743.

Widegren, S. 2014. Introduction of heifers to an automatic milking system. BSc Thesis. Swedish Univ. of Agricultural Sciences, Uppsala.

Wirtz, N., E. Tholen, H. Spiekers, W. Zahres, E. Pfeffer, and W. Trappmann. 2004. Comparison between automatic and conventional milking concerning milk performance and feed amount. Zuchtungskunde 76:321-334.

Woodford, K. B., M. H. Brakenrig, and M. C. Pangborn. 2015. New Zealand case studies of automatic-milking-systems adoption. Pages 127-131 in Proc. N Z Soc. Anim. Prod., Dunedin, New Zealand.

Yule, I. and C. Eastwood. 2011. Challenges and opportunities for precision dairy farming. In Proc. 11th Int. Conf. on Precision Agriculture, Indianapolis, IN, USA.

Zecconi, A., R. Piccinini, G. Casirani, E. Binda, and L. Migliorati. 2003. Effects of automatic milking system on teat tissues, intramammary infections and somatic cell counts. Ital. J. Anim. Sci. 2:275–282.

**Canadian Dairy Producers' Transition to Automatic Milking Systems:
A National Survey Study (General Survey)**

1. Farm Name: _____

2. Email: _____

3. Province: British Columbia   Alberta   Saskatchewan   Manitoba
                   Ontario   Quebec   New Brunswick   Nova Scotia
                   Prince Edward Island

4. When did you install your AMS? (MM/YYYY) _____

5. What brand of AMS system (e.g., DeLaval, Lely, etc.) did you install? _____

6. Did you change housing system (e.g., tie stall to free stall)?   Yes   No   First Farm

7. If you selected 'yes' for [the question above], what type of farm did you have previously?
    Free stall   Tie stall   Bedding Pack

8. Did you build a new barn?   Yes   No

9. How many employees work at the farm? ____ full-time, ____ part-time

10. How many employees worked at the farm prior to transitioning to AMS? _____ full-time, _____ part-time

11. What is your average milk yield (over the past year)? _____kg/cow/day, or _____kg/cow/year

12. How has milk yield changed on a per cow basis after transitioning to AMS?
    Increased   Decreased   Stayed the same

13. What is your average bulk tank SSC (over the past year)? _____ cells/ml

14. How has bulk tank SCC changed after transitioning to AMS?

        Increased   Decreased   Stayed the same

15. On average, how often are cows milked in the AMS unit per day? _____ times/day

16. How much time did you spend milking PRIOR to AMS (including moving cows to parlour, preparing parlour, milking time and cleaning milking parlour)? _____ hrs/day

17. How much time do you currently spend milking (including fetching cows, preparing and cleaning AMS units)? _____ hrs/day

18. How many lactating cows did you milk prior to transitioning to AMS? _____

19. How many lactating cows do you milk currently? _____

20. How many AMS units (robots) do you have? _____

21. What type of robots do you have?   Free flow   Directed traffic: feed-first
                                                Directed traffic: lying-first

22. Is there any training done with the cows prior to first milking with the robot?   Yes   No

23. Do you use a training program for heifers?   Yes   No

24. How many days on average does it take to train a cow? A heifer? _____, _____ days

25. How long did it take your lactating herd to become adapted to the robot (during transitioning)? _____ months

26. Did you have any cows that were not able to adapt to the robot?   Yes   No

27. How many cows did you cull when transitioning to the AMS for not adapting to the robot (**lazy cows only**, not other confirmation or production issues)? _____ cows

28. On a scale of 1 – 5 (1- strongly agree, to 5- strongly disagree), how would you rate the following statements:

    a) AMS has improved profitability   1 2 3 4 5
    b) AMS has improved quality of my life   1 2 3 4 5
    c) AMS has improved quality of my cows' life   1 2 3 4 5

29. Could you name two improvements to your quality of life since transitioning to AMS? (Please provide answer in the space below)

30. Is there anything you miss from your previous lifestyle with the milking parlour? (Please provide answer in the space below)

31. Could you name two challenges you had during transitioning to AMS? (Please provide answer in the space below)

32. What were your solutions to these two challenges? (Please provide answer in the space below)

33. On a scale of 1 – 5 (1- strongly agree, to 5- strongly disagree), were your expectation met after transitioning to AMS?   1   2   3   4   5

34. Would you recommend switching to AMS to other farmers?   Yes   No

35. Would you be willing to participate in a more detailed, online survey that will take a maximum of 30minutes?   Yes   No

If you are interested, a link to the survey will be emailed to you (please ensure Q2 is completed).

Thank you kindly!

Canadian Dairy Producers' Transition to Automatic Milking Systems: A National Survey Study (Combined Survey)

SECTION 1 – GENERAL INFO

1. Farm Name: _____

2. Email: _____

3. Province: British Columbia   Alberta   Saskatchewan   Manitoba
                  Ontario   Quebec   New Brunswick   Nova Scotia
                  Prince Edward Island

4. You are: Full owner   Part owner   Employee responsible for herd

5. Are you the primary decision maker?   Yes   No

6. Age: Under 35   35 – 45   46 – 56   Over 56

7. Gender: Male   Female

8. Education: Complete or partial high school education
                        Complete or partial college/university education
                        Complete or partial postgraduate studies

9. When did you install your AMS? (MM/YYYY) _____

10. What brand of AMS system (e.g., DeLaval, Lely, etc.) did you install? _____

11. Did you change housing system (e.g., tie stall to free stall)?   Yes   No   First Farm

12. If you selected 'yes' for [the question above], what type of farm did you have previously?
                Free stall   Tie stall   Bedding Pack

13. Did you build a new barn?   Yes   No

14. How many employees work at the farm? ____ full-time, ____ part-time

15. How many employees worked at the farm prior to transitioning to AMS? ____ full-time,
                                                                                    ____ part-time

16. On a scale of 1-5 (1-very small workload, to 5- very heavy workload), how would you
characterize your average annual workload after switching to AMS?   1   2   3   4   5

17. What top 3 sources of information did you consult prior to adopting the AMS system?
        Supplier of AMS ("Dealer")
        Technical farm magazines and newspapers
        Newsletters
        Local/regional meetings (educational or industrial)
        Research papers or university extension fact sheets
        Veterinarians
        Consultants
        Other farmers
        On-farm demonstrations/workshops
        TV or radio programs
        Instructional videos and DVDs
        Webinars
        Podcasts
        Blogs
        Other:_____
        None of the above

18. Were you satisfied with the level of support received from these sources?   Yes   No

19. In particular, were you satisfied with the level of support you received from the FIRST source
you chose?   Yes   No

20. In particular, were you satisfied with the level of support you received from the SECOND source
you chose?   Yes   No

21. In particular, were you satisfied with the level of support you received from the THIRD source
you chose?   Yes   No

22. If you utilize professional advisors, how satisfied are you with the level of support provided (on
a scale of 1- very dissatisfied, to 5- very satisfied)?   1   2   3   4   5

23. Was switching to an AMS system part of a farm succession plan/strategy?   Yes   No

SECTION 2 – MILKING LABOUR MANAGEMENT, PRODUCTION AND QUALITY

1. What is your average milk yield (over the past year)? _____ kg/cow/day, or_____kg/cow/year

2. How has milk yield changed on a per cow basis after transitioning to AMS?
    Increased   Decreased   Stayed the same

3. What is your average milk fat content (over the past year)? _____ %

4. How has milk fat content changed after transitioning to AMS?
    Increased   Decreased   Stayed the same

5. What is your average milk protein content (over the past year)? _____%

6. How has milk protein content changed after transitioning to AMS?
    Increased   Decreased   Stayed the same

7. What is your average bulk tank SSC (over the past year)? _____ cells/ml

8. How has bulk tank SCC changed after transitioning to AMS?
    Increased   Decreased   Stayed the same

9. On average, how frequently do cows visit the robot per day? _____ times/day

10. How many hours per day does the AMS spend milking? _____ hrs

11. How many times are cows fetched per day? _____ times/day

12. What is the average number of cows fetched per robot per day? _____

13. How many hours do you wait before fetching cows in…   a) Early lactation? _____ hrs
                                                            b) Late lactation? _____ hrs

14. How many failed milkings occur per day? _____

15. How much time did you spend milking PRIOR to AMS (including moving cows to parlour, preparing parlour, milking time and cleaning milking parlour)? _____ hrs/day

16. How much time do you currently spend milking (including fetching cows, preparing and cleaning AMS units)? _____ hrs/day

SECTION 3 – HOUSING, MANAGEMENT AND FEED

1. Number of lactating cows (not including dry cows): _____

2. Number of lactating cows prior to AMS (not including dry cows): _____

3. How many AMS units (robots) do you have? _____

4. What type of robots do you have?   Free flow   Directed traffic: feed-first
                                                          Directed traffic: lying-first

5. What type of feed is provided?   Mixed ration   Individual forages

6. Did you switch feeding systems since transitioning to AMS?   Yes   No

7. How many times per day are cows delivered feed in the bunk? _____

8. How has the number of times feed is delivered to cows changed since transitioning to AMS?
        Increased   Decreased   Stayed the same

9. How many times per day is feed pushed up to cows in the bunk? _____

10. How has the number of times feed is pushed up to cows changed since transitioning to AMS?
        Increased   Decreased   Stayed the same

11. How many groups of lactating cows do you manage? _____

12. If multiple groups are managed, are cows grouped by any criteria?   Yes   No

13. If you selected 'yes' to the question above, what are the criteria? (Please provide answer in the space below)

14. How many lying stalls do you currently have? _____

15. What is the total length of the feed bunks? _____ inches, or _____cm

16. What type of feed barrier do you use?   Rail   Headlocks   Other: _____

17. If using headlocks, how many headlocks are there? _____

18. How wide are the headlocks? _____ inches or ____ cm

19. Is your barn:　　　　Free stall　　　Bedding pack

20. How wide are free stalls spaced? _____ inches, or _____ cm

21. If you have bedding pack, how much space is available for the lactating cows? _____ feet^2, or
_____ metres^2

22. What type of bedding do you use with AMS?
　　　　　　Deep-bedding: sand
　　　　　　Deep-bedding: shavings/sawdust
　　　　　　Deep-bedding: other
　　　　　　Rubber mat/mattress/water mattress

23. If you selected 'Deep-bedding: Other', please specify what kind: _____

24. If you use rubber mats/mattresses/water mattresses, do you use bedding on top?　Yes　No

25. If you selected 'yes' to the question above, what type?　　Sand　　Shavings/sawdust
　　　　　　　　　　　　　　　　　　　　　　　　Other: _____

26. How often are stalls cleaned (i.e., dirty bedding and manure scraped out) per day? _____

27. How often is fresh bedding added to stalls? _____

28. How much fresh bedding is added to stalls? _____ lbs, or _____ kg, or _____

29. How frequently is the barn alleys cleaned per day? _____

30. How is the barn alleys cleaned?　　Automatic scraper　　Tractor/skid-steer scraped
　　　　　　　　　　　　　　　　Slatted floor

31. What type of water source is used?　　Bowl　　Trough　　Both

32. How many bowls are there in total? _____

33. How many troughs are there in total? _____

34. If troughs are used, what is the volume of the trough? ____ x ____x ____ inches, or

____ x ____ x ___ cm

SECTION 4 – COW HEALTH

4.1 General

1. Have your health management practices changed since transitioning to AMS?   Yes   No

2. What are the two main animal health issues that have occurred since transitioning to AMS? (Please provide   answer in the space below)

3. What are the two main health issues that have improved since transitioning to AMS? (Please provide answer in the space below)

4. Has AMS made health detection easier?   Yes   No

5. If you selected 'yes' to the question above, how so? (Please provide answer in the space below)

6. Has AMS made health detection more difficult?   Yes   No

7. If you selected 'yes' to the question above, how so? (Please provide answer in the space below)

8. What data is the most valuable for detecting health issues? Please rank the following options from 1 (most valuable) to 5 (least valuable).
- o   Activity levels   _____
- o   Milking frequency   _____
- o   Robot visit frequency _____
- o   Milk yield   _____
- o   Milk abnormalities   _____

9. From whom do you get information for managing cattle health in the AMS system? (Check all that apply)　　　　　　Veterinarian　　　　　AMS advisor　　　　Other: _____

10. Please rank these in order of your opinion of how much they cost your business (1 - affects your business the most, to 3 - affects your business the least):
    - o Lameness _____
    - o Mastitis _____
    - o Fertility _____

11. Do you use any type of activity/behavior monitors with your AMS?　　　Yes　　No

12. If you selected 'yes' to the question above, what type do you use? (Check all applicable)
    Activity collar
    Activity and rumination collar
    Leg activity
    Other: _____

13. If you use any type of activity/behaviour monitors, for what purpose do you use them? (Check all applicable)
    Heat detection
    Disease detection: lameness
    Disease detection: metabolic disorders
    Disease detection: mastitis
    Calving
    Other: _____

4.2 Lameness

1. Has your rate of lameness changed since transitioning to AMS?
    Increased　　　Decreased　　Stayed the same

2. Have you been more able to detect lame cows since transitioning to AMS?　　　Yes　　No

3. If you selected 'yes' to the question above, why?
    More time observing cows　　　　　Automatic detection
    Other: _____

4. What management practices did you implement to deal with lameness since transitioning to AMS?

                  Improve housing
                  Improve flooring
                  Improve hygiene
                  Improve comfort
                  Hoof trimming
                  Footbath protocol
                  Genetics (leg/feet conformation)
                  Other: _____

5. Have you been more likely to cull lame cows since transitioning to AMS?   Yes   No

4.3 Mastitis

1. Has your rate of clinical mastitis changed since transitioning to AMS?
                  Increased   Decreased   Stayed the same

2. How many cases of clinical mastitis have you had over the past year? _____

3. On average, how many cases of clinical mastitis did you have before transitioning to AMS? _____

4. Has your bacterial count changed since transitioning to AMS?
                  Increased   Decreased   Stayed the same

5. What is your bacterial count (over the past year)? _____

6. What was your bacterial count before transitioning to AMS? _____

7. How do you detect clinical mastitis? (Please provide answer in the space below)

8. Have you been more likely to cull cows with mastitis since transitioning to AMS?   Yes   No

4.4 Fertility

1. What is your primary tool for heat detection?   ☐ Activity/Behaviour monitor
                                          ☐ Other: _____

2. Has your approach to heat detection changed?   Yes   No

3. If you selected 'yes' to the question above, how has your approach changed? (Please provide answer in the space below)

4. Has your conception rate changed since transitioning to AMS?

                  Increased   Decreased   Stayed the same

4.5 Culling

1. Has your culling rate changed since transitioning to AMS?

                  Increased   Decreased   Stayed the same

2. By how much has your culling rate changed since transitioning to AMS? _____ %

3. How many cows did you have to cull because of the transition to AMS? _____

4. What have the 3 most important reasons for culling been since transitioning to AMS? (Please provide answer in the space below)

SECTION 5 – TRAINING

1. Is there any training done with the cows prior to first milking with the robot?   Yes   No

2. Do you use a training program for heifers?   Yes   No

3. How many days on average does it take to train a cow? A heifer? _____, _____

4. How long did it take your lactating herd to become adapted to the robot (during transitioning)? _____ months

5. Did you have any cows that were not able to adapt to the robot?   Yes   No

6. How many cows did you cull when transitioning to the AMS for not adapting to the robot (**lazy cows only**, not other confirmation or production issues)? _____ cows

7. Did training occur before calving?   Yes   No

8. What group size do you use during training?   < 20   20 - 40   40 – 60   > 60

9. How frequently (number of times per day) were cows required to visit the robot during the first week of training? _____ times/day

10. How frequently (number of times per day) were cows required to visit the robot during the 2nd week of training? _____ times/day

11. During cow training do you: a) Provide feed?   Yes   No
                                    b) Spray teats?   Yes   No

12. During heifer training do you: a) Provide feed?   Yes   No
                                     b) Spray teats?   Yes   No

13. Do you supervise the first milking of a heifer?   Yes   No

14. What is your fetching rate during training (first two weeks)? _____

15. During training (first two weeks), how late do you allow cows to be before fetching?
                   < 2 hours   2 – 4 hours   4 – 6 hours   > 6 hours

SECTION 6 – QUALITY OF LIFE

1. On a scale of 1 – 5 (1- strongly agree, to 5- strongly disagree), how would you rate the following statements:
        a)   AMS has improved profitability   1   2   3   4   5
        b)   AMS has improved quality of my life   1   2   3   4   5
        c)   AMS has improved quality of my cows' life   1   2   3   4   5

2. Could you name two improvements to your quality of life since transitioning to AMS? (Please provide answer in the space below)

3. Is there anything you miss from your previous lifestyle with the milking parlour? (Please provide answer in the space below)

4. Could you name two challenges you had during transitioning to AMS? (Please provide answer in the space below)

5. What were your solutions to these two challenges? (Please provide answer in the space below)

6. On a scale of 1 – 5 (1- strongly agree, to 5- strongly disagree), were your expectation met after transitioning to AMS?   1   2   3   4   5

7. Would you recommend switching to AMS to other farmers?   Yes   No

SECTION 7 – Milk Recording Program

1. Are you a participant in a milk recording program (e.g., DHI/Valacta)?   Yes   No

2. If you selected 'no' to the question above, were you prior to transitioning to AMS?   Yes   No

3. Are you satisfied with the information that you can retrieve from the computer program of the AMS?   Yes   No

4. If you selected 'no' to the question above, what would you like to see improved? (Please provide answer in the space below)

SECTION 8 – Dairy Code of Practice

1. On a scale of 1-5 (1-limited, to 5- extensive), how would you rank your knowledge of the requirements of the Dairy Code of Practice?   1   2   3   4   5

2. Did you refer to the Code of Practice when making plans to transition to AMS?   Yes   No

3. On a scale of 1-5 (1-no improvement, to 5- significant improvement), how would you rank the impact AMS has had with regards to how well your farm follows the requirements of the Dairy Code of Practice?   1   2   3   4   5

Thank you kindly!

APPENDIX 3: DAIRY CODE OF PRACTICE AND AUTOMATIC MILKING SYSTEMS

- A SUMMARY OF RESULTS

The Code of Practice for the Handling and Care of Dairy Cattle (**DCOP**) was developed by the National Farm Animal Care Council and Dairy Farmers of Canada. The DCOP considers current dairy management practices and identifies welfare hazards and ways to assure animal welfare (National Farm Animal Care Council, 2009). The DCOP is science-informed and includes requirements and recommendations for best practices on dairy farms. However, usage of and compliance to the Dairy COP on AMS farms has not been documented.

A subset of 11 recommendations in the Dairy COP were addressed in the survey. Compliance was calculated by comparing producers' responses to the subset of recommendations. For example, question 24 in 'Section 3 – Housing, Management and Feed' of the Combined Survey asked "If you use rubber mats/mattresses/water mattresses, do you use bedding on top?" This question was used to calculate compliance in the recommendation to provide bedding when using mattresses (page 7; National Farm Animal Care Council, 2009).

On a scale of 1 to 5 (1-limited, to 5-extensive), producers ranked their knowledge of the requirements of the Dairy COP a neutral score of 3 (IQR: 2 – 4). Producers' self-ranked knowledge of Dairy COP requirements were not associated with producers' age groups. The COP was used as a source of reference when making plans to transition to AMS to 20% of producers. Producers believed that their AMS has had a positive impact on how well their farm currently follows the requirements of the Dairy COP: the median score on a scale of 1 to 5 (1-no improvement, to 5-significant improvement) was 4 (IQR: 3 – 4).

Compliance to a subset of 11 recommendations in the Dairy COP was high (> 85% compliance) for 9 of the 11 recommendations. In the subset of recommendations, 6 were in 'Section 1 Accommodation, Housing and Handling Facilities', 3 in 'Section 3 Health and Welfare Management' and 2 in 'Section 2 Feed and Water'. The only exceptions, with poor compliance, were for the recommendations on providing adequate linear feed bunk space per cow in 'Section 1 Accommodation, Housing and Handling Facilities' and 'Section 2 Feed and Water' (Table A3.1).

Currently, the Dairy COP addresses dairy farming in terms that are often neither specific to CMS nor AMS. A revision to the Dairy COP that incorporates the differences in dairying with AMS is essential, as the use of this technology is growing in popularity. Furthermore, a revised Dairy COP with improved relevance to AMS may increase the currently low use of the Dairy COP as a source of reference when making plans to adopt this technology. Increasing the use and awareness of the Dairy COP with upcoming AMS farms may increase overall industry compliance to requirements and recommendations.

Table A3.1: Compliance to a subset of AMS-applicable Dairy COP recommendations that were addressed in the survey

Section	Sub-Section	Recommendation/ Requirement	Compliance	n
1 - Accommodation, Housing and Handling Facilities	1.1 - Housing Systems	1.1.2a - provide bedding even when using mattresses	96%	53
	1.5 - Space Allowances	1.5a - provide one stall for each cow in each group	94%	62
		1.5f - clean alleyways regularly	100%	65
		1.5g - provide adequate linear feed bunk space (e.g., 24in, 60cm, per cow)	54%	57
	1.7 - Feeding Area	1.7a - in free stall and bedded-pack barns: provide 24in (60cm) per cow fence line feeding space for mature milking cows	54%	57
	1.9 - Pastures, Yards and Transfer Alleys	1.9k - flush and/or scrape alleyways 2-3 times per day	100%	65
2 - Feed and Water	2.2 - Nutrition and Feed Management	2.2f - provide adequate linear feed bunk space (e.g., 24in, 60cm, per cow)	54%	57
		2.2i - ensure continuous access by pushing up feed in the bunk	89%	66
3 - Health and Welfare Management	3.5 - Lameness	3.5c - ensure alleyways are cleaned daily	100%	65
	3.6 - Mastitis	3.6g - use a stocking density of at least one stall per cow	94%	62
	3.10 - Manure Management and Cleanliness Scoring	3.10a - scrape or flush traffic area and walkways daily	100%	65