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**Producer perceptions of manual and automated milk feeding systems for dairy calves in
Canada**

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ABSTRACT

As part of a cross-sectional survey, Canadian dairy producers were asked a set of questions to: (1) determine factors that influenced them to continue using manual milk feeding (MMF) systems or to switch to automated milk feeders (AMF), and (2) investigate producers' perceived advantages and disadvantages regarding both feeding systems. A total of 670 responses were received. Among respondents, 16% used AMF and 84% used MMF. The four most frequent factors that producers reported as important in motivating them to switch to AMF were to raise better calves, offer more milk to calves, reduce labor, and improve working conditions. For MMF farms, investment in equipment and group housing facilities, as well as farm size, were the primary reasons reported for their continued use of MMF systems. The principal perceived advantages of having an AMF were that calves are able to express natural behaviors and drink more milk without increased labor input. For MMF systems, the main perceived advantage was related to easier identification of sick calves. Results provide insights into factors affecting the choice of calf feeding methods by dairy producers, and improve understanding of producers' needs and expectations regarding calf management and adoption of technology.

Short title: *C. Medrano-Galarza et al.* Perceptions of milk feeding systems for calves.

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INTRODUCTION

There are different management approaches to feed milk to dairy calves, which can be categorized as manual milk feeding (**MMF**) and automated feeding. The former is the most common milk feeding system in North America (Vasseur et al. 2010; USDA 2016), where calves are mainly fed through buckets (i.e., open buckets) or artificial teats (e.g., teat buckets, teat bottles or multiple teat milk bars). In the United States (USDA 2016) and in the province of Quebec, Canada (Vasseur et al. 2010), 72% and 92% of producers, respectively, reported feeding milk using buckets. Calves fed through MMF systems are typically housed individually and traditionally fed restricted volumes of milk (10% of their BW in milk per day on average; Khan et al. 2011). On the other hand, automated milk feeders (**AMF**) are computer-controlled systems that can facilitate the increase of daily milk allowance and group housing of calves, while also retaining the benefits of feeding calves individually (de Passillé et al. 2004; Käck and Ziemerink 2010; Jensen and Weary 2013). Automated feeders have the potential to be used to predict illness before the onset of clinical signs, by closely monitoring calf feeding behaviour (Svensson and Jensen 2007; Borderas et al. 2009a; Knauer et al. 2017).

Decision-making for a dairy producer is influenced by efficiency, food safety, consumer choices, and the care of the animals (Bewley 2013; Endres 2013). Economic return is a crucial factor that influences technology adoption, among other factors such as the producer's age, farm size, and other producers' experiences (Bewley 2013). To date, research on reasons for adopting new technologies has mainly focused on automatic milking systems (**AMS**). In North America, the top two reasons for adopting AMS were allowance for a more flexible labor schedule and savings in the cost of hired labor (de Jong et al. 2003). Nevertheless, the investment required has reportedly been one of main reasons for non-adoption of AMS (Butler et al. 2012; Bergman and

Rabinowicz 2013). Interest in AMF is growing among producers in North America (Endres, 2015), but research on the adoption and the use of AMF is limited (Barkema et al. 2015).

A better understanding of producers' motivations around decisions related to calf feeding systems, and the perceived barriers to adoption of new technologies in the dairy industry is needed. Therefore, the objectives of this study were to determine factors that influenced producers to continue using MMF systems or to switch to AMF, and to gather information about advantages and disadvantages perceived by producers regarding both feeding systems.

MATERIALS AND METHODS

The present study was part of a cross-sectional online survey of dairy calf management practices among farms using MMF and AMF systems in Canada that was conducted from January through May 2015. This survey was administered via a web-based survey platform (FluidSurveys, SurveyMonkey product, Ottawa ON, Canada), and it was reviewed and approved by the University of Guelph Research Ethics Board (REB#14JN025).

Dairy producers registered in the two dairy milk recording services in Canada (CanWest DHI, Guelph, Ontario; Valacta, Sainte-Anne-de-Bellevue, Quebec; implied sampling frame ~80% of dairy producers in Canada) received an introductory letter and the hyperlink to the survey. Additionally, the survey was advertised in dairy cattle magazines and on social media. Detailed description of the survey development, administration and data handling are presented in Medrano-Galarza et al. (2017). Briefly, the survey consisted of 2 questionnaires with closed- and open-ended questions; one questionnaire was for producers using MMF systems (i.e., milk offered via open bucket or teat [bottle, bucket, milk bar]), and one questionnaire was for producers using AMF (i.e., computer-controlled systems). Both questionnaires collected the

same type of information, but questions were phrased differently to be consistent with the milk feeding system being used. Questionnaires started with an identical section: generalities of the farm (e.g., location, breed of cattle, type of housing). At the end of this first section, producers were asked what type of automated devices they had on their farm, and based on their answer for AMF (i.e., yes/no question), they were directed to the corresponding questionnaire.

To address the objectives of this study we used the survey questions related to factors influencing decision-making and perceptions (i.e., advantages and disadvantages) of respondents' current calf milk feeding system. Specifically, using symmetrical 5-point Likert scales, respondents rated a series of statements regarding possible influential factors for adopting AMF or continuing to use MMF systems (1 = important to 5 = not important), and perceived advantages and disadvantages of the systems (1 = agree to 5 = strongly disagree). Optional open text boxes were provided to allow producers to complement the ordinal response and to expand on their answers. Full-length questionnaires are available as supplementary data.

Descriptive statistics (proportions) were calculated, and Chi Squared and Wilcoxon Two-sample tests were used to evaluate differences in categorical and continuous variables, respectively, between farms with AMF and MMF systems, using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA). Complementary responses added by respondents in the open fields were open-coded and themes identified. Themes were used as categories for analysis, where each given response was classified based on common patterns of information (Boyatzis 1998).

RESULTS

General Description of Producers and Farms

A total of 670 dairy producers across Canada were included in the analysis, representing 6% of all dairy farms in Canada (CDIC 2015). Of the respondents, 16% (n = 105) used AMF to raise

calves, and 84% ($n = 565$) used MMF systems. The respondents were from all 10 Canadian provinces (Figure 1). Language, gender, and age of respondents did not differ between AMF and MMF farms ($P > 0.4$). The majority of respondents completed the survey in English (79%; $n = 532$), and most respondents (72%; $n = 473$) were male. Ages of respondents were: < 25 yr (8%; $n = 51$), 25 to 34 yr (27%; $n = 177$), 35 to 44 yr (22%; $n = 147$), 45 to 54 yr (29%; $n = 195$), and ≥ 55 yr (14%; $n = 96$).

Overall, the average reported herd size was 90 milking cows (range: 17 to 2800). Farms with AMF were significantly ($P < 0.001$) larger (median [25th - 75th percentiles]: 110 milking cows [66 - 150]) compared to farms with MMF systems (median [25th - 75th percentiles]: 60 milking cows [45 - 100]). For more details on farm demographics see Medrano-Galarza et al. (2017).

The majority of farms using AMF had one feeder (86%); 11%, 2%, and 1% of the farms had 2, 3, or 6 feeders, respectively. Within farms using MMF, 53% used teats (bottles, teat buckets and/or milk bars) to feed calves for at least the first 2 mo of life, while 36% of farms fed milk through open buckets, and 11% used a mix of teat and open bucket to feed milk. Most MMF farms (86%) fed calves 2 times/d. Only 10% fed calves 3 times/d, while 1% fed 4 times/d, and 3% reported feeding calves “*ad libitum*”.

Factors Influencing Decision-making Regarding Milk Feeding System for Calves

From a list of potential factors that might have motivated producers to switch from MMF systems to AMF, the 4 most frequent factors reported as being important by producers ($n = 105$) from AMF farms were to: raise better calves, offer more milk to calves, reduce labor, and improve working conditions (Figure 2). Sixteen of these producers (15%) provided additional information in an open-ended response regarding what factors influenced them to switch to AMF; 6 of them gave more than one additional factor. These responses included: consistency of

feeding (e.g., constant quantity, temperature; 31%), allow calves to be fed multiple times a day (31%), reduce stress on calves at weaning (19%), seeking time flexibility (13%), better data management (6%), easy way of combining whole milk and milk replacer (6%), continuous calf access to warm milk (6%), and desire to switch to group housing (6%). Figure 3 describes these factors and how they relate to each other.

Among producers using MMF, the most frequent factors reported as influencing their decision to continue using this feeding system were the economic investment involved in changing to automated systems, and small farm size (Figure 4). A total of 150 producers (26%; total n = 565) provided more information in the open-ended response regarding what have influenced them to continue feeding calves manually or have them housed individually; 55 of those producers gave more than one reason. Thirty-nine percent of the 150 producers said that they preferred individual manual feeding and housing because of the direct contact with each calf at milk feeding time, which allowed them to observe calves and identify any change in feeding behaviour and health, while 16% of producers preferred the direct contact with calves because it allowed them to raise calmer calves that are easier to handle (“... tame from birth and very easy to work with throughout their life”). Twenty-three percent of producers believed that reduced disease transmission and healthier calves were easier to achieve when calves were kept in individual housing. Another 11% of producers indicated that they felt satisfied with how they were managing calves, and thus they were not interested in changing something that was already working well. Other influential factors included: concerns about cross-sucking between group-housed calves (4%), family roles (i.e., children or a member of the family were in charge of feeding calves and that manual feeding was “giving them a sense of responsibility” or “something to do”; 3%), concerns about the cleanliness of AMF systems (3%), lack of concerns

about labour (i.e., having enough personnel to feed calves manually; 2%), not having reliable personnel to handle AMF technology (1%), and, being close to retirement (1%). Four producers (3%) reported having previously used feeders but switched back to manual feeding due to health and cross-suckling problems. Figure 5 describes these factors and how they relate to each other.

Perceived Advantages and Disadvantages of Automated and Manual Milk Feeding Systems

Advantages of Automated Milk Feeders

The advantages to using AMF perceived by producers are presented in Figure 6. The top 4 advantages of having AMF (perceived by more than 90% of producers from farms using this technology) were that these devices allowed calves to express natural behaviours, that producers could increase calf milk allowance without increasing labor, that farm working conditions were improved by AMF, and that workers spent less time cleaning feeding equipment. Additionally, 82% of producers agreed or strongly agreed that having an AMF facilitated management of group-housed calves, and 68% also agreed that detection of illness could be done earlier. Eleven producers (10%) provided additional factors in the open-ended response about the perceived advantages that brought to their farm (one producer listed more than one advantage). Of these, 36% indicated that AMF have allowed them to wean calves very gradually and the process seemed less stressful on the calves. Consistency of feeding in terms of quantity of milk powder, volume, and temperature were also reported as an advantage (39%). Other advantages reported by producers were that calves begin water and solid feed consumption faster compared to calves in hutches (9%); feeding through AMF was actually cheaper than the “old way” (9%); and that calves were less stressed when moved to larger group pens (because of group housing) (9%).

Advantages of Manual Milk Feeding Systems

The advantages to using MMF perceived by producers are presented in Figure 7. The majority of producers from farms using MMF systems perceived that the direct contact that they had with calves at feeding time facilitated the identification of sick animals, facilitated handling, and decreased risk of disease transmission. Sixty-one producers (11%) provided additional advantages in the open-ended field. Of these, 41% remarked on the advantage of being able to monitor health and feeding more easily when calves were fed manually and housed individually, and thus being able to intervene faster when necessary. Individualized feeding and, thus, no competition between calves, was an advantage reported by 15% of the 61 producers, while 12% highlighted the low capital cost of feeding milk by hand. Fresh air, available to calves in individual hutches, was perceived as another advantage by 7%. Other advantages noted were: cleaning of buckets was fast and easy (5%), producers were able to know each calf's personality (3%), measuring weight of calves housed individually was more practical than group-housed calves (2%), and feeding milk manually was an activity that the producer actually enjoyed (2%).

Disadvantages of Automated Milk Feeders

The disadvantages to using AMF perceived by producers are presented in Figure 6. Less direct contact with calves was identified as the top disadvantage (40% of producers) of using AMF among producers using these feeders. Twenty-two producers using AMF (21%) provided additional detail about the disadvantages they perceived from AMF in open-ended responses. Of these, 23% indicated that they had concerns about sanitation of the feeding system; 36% reported having cross-sucking issues; and 14% perceived that disease transmission increased. Other disadvantages listed by producers were related to increased calf training they had to do (i.e., first train calves to bottle feed and then train them again to the teat at the AMF station; 4%), and the need for appropriately trained staff to be in charge of the feeder (4%).

Disadvantages of Manual Milk Feeding Systems

The disadvantages to using MMF perceived by producers are presented in Figure 7. The majority (56%) of producers strongly agreed that a disadvantage of manual feeding is that it makes it more difficult to increase milk feeding frequency per day. Furthermore, among those using outdoor housing for calves, it was agreed that having to feed calves in winter is not pleasant. Thirty-three producers using MMF systems (6%) provided detail in open-ended responses about the disadvantages they perceived that about MMF systems, and when applicable, the implementation of individual housing. Fifty-six percent of the 33 producers expressed the concern of not having consistency in feeding when multiple people were feeding the calves, and also regarding temperature of the milk. The extra physical labour needed when feeding calves manually was another disadvantage expressed by 15% of producers. Nine percent of producers stated that the lack of socialization and the restriction of movement was the biggest disadvantage of their system. Among other disadvantages listed on the open-ended section were: competition among calves when milk-bars are used (3%); the weaning process is not as “smooth” as it can be with AMF (3%), not able to record data on feeding vigor (3%), and the challenge they face teaching calves to drink from a bucket (6%).

DISCUSSION

This research is the first study that provides insights into Canadian dairy producers’ decision-making and perceptions towards manual and automated milk feeding systems for raising calves.

Farms with Automated Milk Feeders

Research previously done on precision dairy farming has shown that the main drivers for investing in new technologies, such as AMS and sensor systems, were a desire to change lifestyle, increased flexibility in time, reduced labour, increased productivity and profitability, as

well as perceived economic returns (Bergman and Rabinowicz 2013; Bewley 2013; Steeneveld and Hogeveen 2015). Extrinsic factors, such as increased concern about animal care and welfare, and other producers' experiences with the technology, also influence the decisions made by a producer (Bewley 2013). When deciding to invest in an AMF, producers surveyed in this study expressed the desire to be able to raise better calves and increase milk allowance, while reducing labor and improving conditions at work, hence, producers were interested in reducing labor and costs, and were also interested in improving the quality of life of both calves and workers. Similarly, Endres (2016) found that dairy producers in the state of Minnesota purchased AMF mainly looking to decrease time spent on menial tasks, improve calf growth and records on calf feeding, as well as allow for more natural feeding for calves, and improve labor conditions. In the present study we also found that more than half of producers reported that knowledge about other producers' experiences with AMF was an important factor influencing their decision to invest in this technology. Likewise, in a study conducted in Sweden, the most important information source for the adoption of AMS reported by producers was "other milk producers", demonstrating that producers place importance in information and guidance obtained from other producers (Bergman and Rabinowicz 2013).

Calves expressing natural behaviours, being able to give more milk to calves without increasing labor, and improved working conditions were the main advantages perceived by the majority of producers using AMF. Comparing these perceived advantages with the previously mentioned factors that influenced the adoption decision, it can be inferred that AMF fulfilled the expectations producers had when deciding to switch to automation. These results are similar to the findings of Bergman and Rabinowicz (2013) regarding adoption and outcomes associated with installing an AMS. In addition, almost 70% of producers using AMF surveyed in our study

perceived that earlier detection of sick calves was an advantage of this system. Although there are concerns regarding detection of illness in group housing systems, especially when large group sizes are used (Svensson and Jensen, 2007), research has shown that daily monitoring of behavioural data provided by AMF can help to detect sickness before the onset of clinical signs (Borderas et al., 2009a; Knauer et al., 2017).

Producers surveyed in our study also reported that it was easier to manage group-housed calves and to wean them gradually through the use of an AMF (vs. MMF) and that calves started consuming water and solid feed earlier than they did when fed individually. These perceived benefits of AMF result from an interaction between the feeding system (automated) and the housing system (group housing) under appropriate management, the latter being essential for limiting competition and cross-suckling, especially during the weaning period (Steele et al. 2015). Researchers have found that one of the disadvantages of feeding more milk to calves (which is one of the advantages of AMF) is that solid feed consumption is lower during the milk-fed period (Borderas et al. 2009b); but when group housing is implemented, starter intake is stimulated (Jensen et al. 2015). Therefore, what producers see as an advantage of AMF is, in fact, an advantage of the whole system.

On the other hand, the main disadvantages reported by producers using AMF was the decrease in time spent directly in contact calves, which 16% of producers (Figure 4) perceived might lead to more fearful or aggressive calves. Similarly, Bergman and Rabinowicz (2013) found that producers who did not want to install an AMS were concerned about having less contact with the cows. Although there has not yet been research investigating the temperament of group-housed calves specifically raised with AMF, findings from research done comparing handling and fearfulness between individual- and group-housed calves are conflicting. Lensink et al. (2001)

found that pair-housed calves took longer to approach an unfamiliar person and spent less time interacting with the person, and they were less easy to handle than individually housed calves. Similarly, Veissier et al. (1998) found that calves reared in groups were more stressed during handling than calves raised in individual housing. However, Lensink et al. (2001) also found that, irrespective of housing conditions, if additional contact (e.g., petting after milk feeding) was provided, calves' motivation to interact with an unfamiliar person increased and calves were easier to handle. In contrast to these studies, recent research has shown that calves reared in groups were less fearful and food-neophobic than individually-housed calves (Costa et al. 2014). Producers surveyed here who felt they were having little direct contact with calves could increase the frequency of interactions (ensuring they are positive) to potentially reduce the level of fear calves experience during handling.

Farms Feeding Milk Manually

Large investment has been one of the top reasons for the non-adoption of precision dairy technologies (Butler et al. 2012; Bergman and Rabinowicz 2013). In addition, intrinsic factors related to the producer and the farm influence decision-making (Bewley 2013). The main reasons identified by the majority of MMF producers were the cost of equipment and the cost of renovating facilities to fit the new equipment. Similarly, Bergman and Rabinowicz (2013) found that the top two reasons for producers to decide not to install an AMS were the expense of buying the milking robot and large investments for reconstruction in the barn. Moreover, producers from our study also indicated that their farm size was too small to justify the purchase and the use of an AMF. This result is parallel to what we found regarding features of surveyed farms, where larger farms were more likely to have AMF compared to small farms (Medrano-Galarza et al., 2017). Manufacturers promote that an AMF can supply a group of approximately

25 calves per feeding station (Käck and Ziemerink 2010). Therefore, producers with a small number of calves per year might not see benefit in switching to automation when feeding manually is working reasonably well.

What MMF producers in this study liked the most about their feeding system was the direct contact with calves during feeding time, which they indicated allowed them to identify sick calves by looking at changes in behaviour, as well as reduced disease transmission achieved through individual housing and feeding. It has been suggested that individual housing until weaning reduces the risk of pathogen transmission and facilitates surveillance of calves' health status by the producer (Kung et al. 1997; Marcé et al. 2010). Research on group housing is relatively new (Costa et al. 2016); therefore, data related to this housing system are limited.

On the other hand, we found that one of the biggest perceived disadvantages of manually feeding calves was the limitation in the frequency of feedings per day. Feeding higher milk amounts (i.e., 20% of BW in milk) is recommended in the Canadian Code of Practice (NFACC 2009); however, research regarding optimal meal sizes when feeding a high plane of nutrition is still in development and is conflicting. Yunta et al. (2015) found that receiving higher amounts of milk in only 2 daily feedings can have a negative effect on glucose metabolism, emphasizing the need for increasing feeding frequency, while MacPherson et al. (2016) found that it has a minimal effect and did not decrease insulin sensitivity.

In addition, if raised with their dams, calves normally suck milk about 5 to 8 times a day (Phillips 2002); thus, only feeding 2 meals per day is unlike the natural feeding pattern of a calf. Research on feeding labour in conventional systems (i.e., manually feeding milk twice a day) has shown that to feed a single calf through a bucket takes approximately 10 min/d (Kung et al. 1997). Therefore, feeding more frequently would require an increase in labor, which producers

might be reluctant or unable to undertake. This is supported by research on adoption of technologies or implementation of new practices mainly driven by the desire of reducing labour and saving time (Bewley 2013; Hötzel et al. 2014).

Limitations

By using Likert scale questions we could quantify attitudes and opinions towards milk feeding systems and allow producers to indicate a level of importance or agreement with statements rather than forcing them to take a particular position about given statement. However, we could only give limited number of statements, reducing producers' opinions to the options given. The use of open-ended questions helped to limit this drawback and allow producers to expand their responses, if desired. Follow-up with the use of qualitative research methods would allow for more in-depth understanding of producers perceptions and fuller exploration of the factors related to use of milk feeding systems.

CONCLUSIONS

The key motivators indicated by dairy producers for adoption of AMF included: to raise better calves, give more milk to calves, reduce labor, and improve working conditions; the key barriers were mainly costs related to investment in the equipment and group housing facilities. The main perceived advantages of an AMF were to allow calves to express more natural feeding behaviour and drink more milk without increasing labor, indicating that producers experienced the expectations that motivated them to adopt this technology. In contrast, easier disease detection and handling of calves were the positive aspects perceived by producers feeding milk manually to their calves.

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For Review Only

Figure 1. Distribution of respondents (with 95% CI) from an online questionnaire completed by 670 dairy producers (Jan-15 to May-15) and of all Canadian dairy farms (Canadian Dairy Information Center, 2015) by region (Western provinces = British Colombia, Alberta, Saskatchewan, and Manitoba [n = 153]; Ontario [n = 322]; and Quebec and Atlantic provinces = New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador [n = 195])

Figure 2. Level of importance reported by 105 producers with automated calf milk feeders for a list of potential factors influencing their decision to switch from manual milk feeding systems to automated milk feeders to raise calves (responses from an online questionnaire; Canada, January 2015 to May 2015)

Figure 3. Factors influencing producers’ decision to switch from manual milk feeding systems to automated milk feeders to raise calves, and how these factors relate to each other (arrows). Factors of influence (thinner circles) are grouped into main themes (represented by thicker circles). The themes are derived from the responses to closed-ended questions (Likert scales) regarding decision-making statements and the analysis of the 16 responses to open text comment boxes in an online survey with 105 respondents using automated calf milk feeders

Figure 4. Level of importance reported by 558 producers for a list of potential factors influencing their decision to continue using manual milk feeding systems to raise calves; AMF = automated milk feeder (responses from an online questionnaire; Canada, January 2015 to May 2015)

Figure 5. Factors influencing producers’ decision to continue using manual milk feeding systems to raise calves, and how these factors relate to each other (arrows). Factors of influence (thinner circles) are grouped into main themes (represented by thicker circles). The themes are derived from the responses to closed-ended questions (Likert scales) regarding decision-making statements and the analysis of the 150 responses to open text comment boxes in an online survey with 565 respondents using manual milk feeding systems; AMF = automated milk feeder

Figure 6. Level of agreement reported by 97 producers using automated milk feeders (AMF) with a list of statements regarding potential advantages and disadvantages that AMF brought to their farms (responses from an online questionnaire; Canada, January 2015 to May 2015)

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Figure 7. Level of agreement reported by 548 producers using manual milk feeding systems (MMF) with a list of statements regarding potential advantages and disadvantages that MMF brought to their farms; MR= milk replacer (responses from an online questionnaire; Canada, January 2015 to May 2015)