ABSTRACT

Dairy farms have become more reliant on technology. The overall aim of this study was to better understand how dairy farmers view technology and its effects on animal care, including their views on the prospect of integrating gene-editing technology in the future. Virtual-semistructured interviews were conducted with dairy farmers (n = 11) from British Columbia and Alberta. To facilitate discussion, the participants were asked to develop and discuss a timeline describing when and why various technologies were adopted on their farm. Although farmers defined technology broadly and affecting multiple aspects of farm management, this paper focuses on their views regarding how technology can affect animal care. Following thematic analysis of the data, the following 3 themes emerged: (1) the changing role of the farmer (including intergenerational considerations and learning new technology), (2) the effect of technology on the cow and her relationship with the farmer and, (3) technology as the future of the farm. The discussions also highlight the concerns that some farmers have regarding challenges associated with reduced human-animal interactions and effective use of the large amounts of data that are collected through technology. We also specifically asked the participants their views about gene editing as a potential future technology. Most of the participants did not specifically address their views on gene editing, but they spoke about the effect on genetic technologies more generally, often making references to genomic testing. However, some questioned how this technology may affect farmers more generally and spoke about how it could affect human-animal relationships. These results illustrate differences among farmers in the way they view technology and how this can affect the dairy cattle they care for.

Key words: views, robotic milking, gene editing, automated milking systems

INTRODUCTION

There is a long history of adopting new technologies on dairy farms, including wide spread use of artificial insemination, embryo transfer, sexed semen and more recently gene-editing technologies (Wright et al., 2022). Another important twentieth-century innovation in dairy farming was the introduction of the milking machine; the jumping off point for various automated parlor systems culminating more recently with automated milking systems (AMS; reviewed by Garlindo and Sauer, 2018). The adoption of AMS has reduced the requirement for human labor (Sonck and Donkers, 1995; de Koning et al., 2003) while allowing for an increased number of milkings per day (Gallardo and Sauer, 2018). Indeed, much technology aims to reduce labor or otherwise improve the efficiency of production (Gallardo and Sauer, 2018).

The field of precision dairy farming has also exploded over the last decade with the adoption of individual sensor-based animal monitoring devices such as rumination collars and activity monitors (Knight 2020); each device providing readily available data streams that are increasingly being integrated into the day-to-day management of dairy farms (see review by Halachmi et al., 2019). These technologies allow for monitoring individual animals (Borchers and Bewley, 2015), and collect data often thought to be relevant to health or welfare (Weary and von Keyserlingk, 2023).

Given the increased availability of technology for dairy farms, it is important to understand the farmer’s perspectives on technology use and how technologies can affect their life (e.g., Henchion et al., 2022), and the lives of their cattle. A French study found that farmers believed that technology improved working conditions, and helped them to address economic and regulatory incentives (Kling-Eveillard et al., 2020). Lundström and Lindblom (2021) found that Swedish farmers who adopted AMS reported less physical strain, increased flexibility in their job, decreased dependency on hired labor and improved udder health outcomes. Reasons provided by farmers who adopted new technology included the perception that it would save labor and increase efficiency (Eastwood et al., 2016). Concerns
about the technology, including affordability, acted as barriers to adoption (Martínez-García et al., 2015).

Farm size appears to be a key factor affecting technology adoption (Gargiulo et al., 2018), likely in part because larger farms often struggle to find labor but also because they typically are able to spread the purchase cost over more animals (Garlindo and Sauer, 2018). Farmers often report that they adopted AMS based on their belief that it will reduce labor, along with increased freedom and flexibility in how they spend their time, although reports indicate that farmer’s work routines are changed rather than reduced (e.g., Sauer and Zilberman, 2012, Denmark; Butler et al., 2012, United Kingdom; Hyde and Engel, 2002, United States). Technologies such as AMS can also alter how farmers interact with their animals (Jacobs and Siegford, 2012).

Our study aimed to document farmers’ views regarding the use of technology, and how this affects their care and relationship with their animals. Given the importance of reproductive and genetic technologies on dairy farms, a third aim of this study was to explore the views of farmers regarding the new gene-editing technologies on their farm.

MATERIALS AND METHODS

The study presented was approved by The University of British Columbia’s Behavioral Research Ethics Board (H20–00913). Data collection took place from June to October 2020.

Reflexivity Statement

Study team members were all part of The University of British Columbia’s Animal Welfare Program, located with the Faculty of Land and Food Systems. Weary and von Keyserlingk have collaborated with one another for over 20 years, with much of their work on the welfare of dairy cattle. The research has been funded by dairy farmer industry organizations and other allied industry partners with matching funds from the Canadian government through the Natural Sciences and Engineering Research Council of Canada Industrial Research Chair Program. Mills completed her PhD in the Animal Welfare Program during which she took courses in qualitative methods and undertook a series of studies that involved conducting interviews, focus groups and other participatory methodologies with dairy industry professionals.

Study Area, Recruitment, and Participants

Individual interviews were conducted with a convenience sample (Miles et al., 2014) of 11 dairy farmers (7 men and 4 women, in all cases the farm owners or family members involved in the day-to-day management of the dairy farm) currently farming in 2 western Canadian provinces (British Columbia, n = 8, and Alberta, n = 3). Of these farms, 5 farms milked <200 cows, 4 farms milked between 200 and 400 cows, 1 milked ~600 cows, and 1 farm milked ~1,200 cows. Five of these farms used AMS; the remainder used conventional or rotary milking parlors. All farms used freestall housing. For context, the large majority of farms in this region use freestall housing and are family owned and operated. The average dairy farm in Alberta milks about 125 cows; whereas, in British Columbia this number is slightly higher at 140 (Government of Canada, 2020). There are 470 and 525 dairy farms in British Columbia and Alberta, respectively. Farm size is likely to continue to increase in the years to come, helping to drive uptake of on-farm automation and other technology.

Recruitment was done with the help of 2 provincial dairy industry organizations (Alberta Milk and the British Columbia Dairy Association). Dairy farmers were asked by the organization if they would prefer to volunteer to participate in the study and those that contacted the research team were given information.

Study Design

The interview guide (Table 1) was pilot tested with 2 volunteers with previous experience working on a dairy farm before the study was initiated; the pilot interviews were not included in the study. Nine of the 11 interviews took place virtually over Zoom (San Jose, CA: Zoom Video Communications Inc.); 2 participants requested phone interviews due to internet limitations or personal preference. All participants were given a brief introduction to the nature of the study and then asked to provide verbal consent; all participants agreed to participate and were told that the recording device would be turned on so enable recording of the interview. When conducting interviews, it is important to quickly build rapport, creating respect and trust between the interviewer and the participants as this has been shown to result in more in-depth data (Dicicco-Bloom and Crabtree 2006); thus, we began the interview with some ice-breaker questions. The interviewer also gave some information about themselves and what their research was focused on. Participants were then asked to complete a timeline mapping exercise, a method also known to build rapport between interviewers and participants and to help guide the interview (Kolar et al., 2015). Using the whiteboard function on Zoom, participant and interviewer worked together to create a timeline depicting when they made the first changes to technology on the farm, including the year and details about
the technology. Participants who completed the interview by phone were asked verbally what technology they had implemented over time, and the interviewer documented the timeline provided. Coinciding with this activity, participants were asked questions about the use of technology on their farm and future plans for technology adoption. Technology has many different definitions (Carroll, 2017); for the purposes of this study the interviewer did not provide a definition and instead allowed participants to discuss what technology meant for them. The 11 interviews ranged in length from 20 to 64 min with the ice-breaker questions focused largely on understanding farm demographics took up on average the first 5 to 7 min. All interviews were audio recorded and manually transcribed by KM and compared with the original files for accuracy. Participants were sent copies of their transcripts and given the opportunity to remove any material or clarify anything that was said (i.e., member checking; Creswell and Miller, 2000).

Analysis

KM conducted the interviews and completed the thematic analysis pertaining to the first 2 aims of the study. The analyses for the third aim were undertaken by an undergraduate student and MAGvK; both have received training in this type of thematic analyses involving interview data.

Qualitative analysis was done using NVivo (Version 12: QSR International Pty Ltd.) with the coders first familiarizing themselves with the transcripts and timelines and taking notes. As such, codes were inductively be applied to fragments of text. Then, patterns in codes are identified as themes, and connections between codes and themes are described (Guest et al., 2014). Once a preliminary list of codes was created, a codebook (Roberts et al., 2019) was developed by sorting individual codes into similar categories and building up to larger themes. This was done as an iterative process, coding multiple times and updating the codebook with each iteration. Labels that provide descriptive meaning to the data were then applied (see Miles et al., 2014). One codebook was used to address the first 2 aims of the study and did not include the responses specific to the gene edition question. Regarding the first 2 aims of the study, analysis of the last 2 interviews revealed no new themes or codes compared with the previous interviews, indicating theoretical data saturation. The responses to the latter question were used to develop a separate codebook specifically focused on addressing the third aim of our study. Data saturation for the final aim was not reached, likely for reasons that are discussed in the limitations section below. For reporting results, quotes from specific participants (P) are identified by a number (1–11). Supporting quotes are embedded in the discussion of themes to ensure participants’ voices remain centered within the research. In some instance they were condensed by removing verbal ticks and repetitive words. Square brackets ([...]) indicate where quotes have been modified.

RESULTS AND DISCUSSION

Given that farm size is likely to continue to increase in the years to come, helping to drive updates of on-farm automation and other technology (Barkema et al., 2015), our study set out to describe how dairy farmers view on-farm technologies. As we did not establish an a priori definition of technology when conducting the interviews, but rather allowed participants to discuss what technology meant to them in the context of their farms, allowing participants to describe the range of examples of different technologies and different effects that these technologies can have on their farms and their management. We also
focused on the role and relationships of the participant and did not go into detail regarding the different people who were involved in the daily care on some of the farms (e.g., employees and different family members). Although participants discussed many aspects of how technology was integrated into their farm management, such as manure management, employee scheduling and administrative tasks, we focus here on how the technologies were perceived to affect animal care. Our thematic analysis identified 3 key themes: (1) the changing role of the farmer, (2) the effect of technology on the cow and the relationship between cow and farmer, and (3) technology as a component of the future of the farm. Each of these themes and the various subthemes are described in the sections that follow (Table 2).

### Changing Role of the Farmer

**Changes in Daily Routines.** Integrating technology on the farm resulted in some farmers feeling that their role as a farmer has changed. By far the most discussed example was the implementation of AMS, with participants frequently commenting on how this technology affected their daily routine and interactions with their animals. For example, one farmer reflected on how their day-to-day management changed after installing AMS:

> I’m a hands-on type of guy and for the first month or two…I felt lost because I didn’t have to be out there to milk the cows at certain times…our whole schedule was thrown haywire…from [one where] I’m out at 5:00 in the morning every day and I’m going till 7:30 before breakfast, and then at 4:00 [I start] chores …, 5:00 or 5:30 I’m back milking until 7:30…[to now where] all of a sudden… I’m done (P9).

The effects of AMS on the farmer’s workday have been reported by others. For instance, Butler et al. (2012) interviewed British farmers and reported that they considered that AMS changed rather than reduced their workload; some farmers reported feeling more tied down after adopting AMS, due to AMS unit alerts arriving at all hours rather than just during a normal workday.

The installation of AMS was viewed positively by many of our participants; for example, one farmer discussed increased flexibility in the work day: “[I would] never go back to milking any other way. We’ve had so many benefits… My kids were in sports and, you know [before], I’d miss hockey practices…missing games on the weekend [because] the milker [is] off. But since the [AMS] went in, I haven’t missed any. [The AMS allows] rearrang[ing], mov[ing] your schedule around to accommodate a lot of that stuff… So huge improvement in

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Table 2. Interview guide followed when documenting views of Western Canadian dairy farmers (n = 11) regarding the use of technology on their farms, and how this affects their care and relationship with their animals

<table>
<thead>
<tr>
<th>Objective</th>
<th>Question[^1][^2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice-breaker questions</td>
<td>What is your role on the farm? How many cows do you milk? Can you tell me a little about how your family got into farming?</td>
</tr>
<tr>
<td>Timeline (rapport-building) exercise</td>
<td>Can you share with me a little of the history of including technology on your farm? For example, when did you first install a bulk milk storage tank, a milking parlor, or perhaps even automated milking system; when did you register with a milk recording service?</td>
</tr>
<tr>
<td>Timelines Questions used to address aims 1 and 2</td>
<td>What are some things you noticed when completing this exercise?</td>
</tr>
<tr>
<td>Data use</td>
<td>Using examples from your timelines, what data are collected with the technology you have incorporated on your farm? How do you use the data that are collected? How do these data influence your decision-making? What do you wish that your current technology would tell you?</td>
</tr>
<tr>
<td>Future technology</td>
<td>Using examples from your timelines, why do you plan on incorporating this technology in the future? What do you want this technology to be able to help you do?</td>
</tr>
<tr>
<td>General technology</td>
<td>What features do you look for when choosing new technology for your farm? What features do you avoid?</td>
</tr>
<tr>
<td>Questions used to address aim 3</td>
<td>Do you consider the use of gene-editing technology on your farm? Where do you see the use of this technology on dairy farms in the future?</td>
</tr>
<tr>
<td>Gene edited technology</td>
<td>Do you have any questions for me? Do you have anything else to add?</td>
</tr>
</tbody>
</table>

[^1]: Semi-structured questions: exact wording of question is not important but the spirit of the question must be adhered to.
[^2]: General prompts to facilitate more discussion on a specific topic if needed: Could you tell me more about that? Could you walk me through that? What do you think was going on there? Would you mind explaining that again so that I can understand.
lifestyle” (P11). Other studies have also reported that farmers felt that the AMS allowed for greater flexibility in their work day (Driessen and Heutinck, 2015; Lundström and Lindblom, 2021) and allowed them to schedule new daily tasks (Kling-Eveillard et al., 2020).

Intergenerational Considerations. In some instances, technology was added to the farm to make it more attractive for the next generation: “…there are three boys in the family. We’ll see if one of them wants to continue [in farming]. It’s a significant financial commitment that we’ve made [installing AMS]. On the other hand, [this change] perhaps makes the farm that much more attractive for the next generation” (P4). New technology can improve working conditions, perhaps making farming a more attractive profession (Kling-Eveillard et al., 2020); this driver may be particularly relevant given the changing employment landscape in agriculture including reduced expectations placed on children to take over the family farm (Villa, 1999).

Some younger participants explained that when they took over the farm, they took the opportunity to integrate new technology on the farm. For example, when one participant took over day-to-day management of the farm, they adopted more milking technology: “My dad’s philosophy was making [practices on farm] mechanical and manual because it works and you can fix it. [I] spearheaded the whole robot project…” (P6). That younger generations are more likely to embrace technology has been reported previously. Vecchio et al. (2020) reported that there was a higher level of adoption of precision farming technology by younger farmers compared with older, more established farmers; a finding that was explained by the younger generation having greater awareness and increased access to information. In our study this difference in views between generations was often discussed in relation to the previous generations hesitation to integrate technology: “…dad still had lots of control [when deciding on a parlor or robots] … We had a tough enough time selling him on putting in the new parlor” (P9). Family farms are predominant in Canada (see Bronson et al., 2019), and technology adoption is affected by family dynamics and history as illustrated in the following response from one participant:

We decided to put in robots; they are retrofitted into our old barn… the barn that the robots are in was actually here when my great grandfather moved here. … built in the late 1800s. And [now there is] a robot in it. So, it’s kind of cool. It’s a lot of history, but [with] the whole spectrum of technology (P6).

Learning to Use New Technology. Participants reflected on how the skills that they had developed to fix equipment might no longer be adequate for new technology (“well, in the good old days, you know, duct tape and hammer could take you a long way” [P4]). Participants expressed a range of responses toward the learning process of integrating and troubleshooting new technology. For example, some discussed that it was a steep learning curve: “At first, whenever I had a problem, whatever it was, I had no idea what to do. Over time, you just learned about the machine and got to know how to fix it and everything” (P6). This was discussed in relation to problems with the new technology:

You know, when everything’s working well, hallelujah, but when things go a little sideways and stuff, you don’t know where to start because you’re not familiar with it. And again, not being that tech savvy then I have to ask for help, I guess as a typical male that’s always hard to do because I was always the “go-to guy” and I’m no longer the “go-to guy” (P4).

Some participants also commented on the challenges that arise when the technology fails to meet their needs causing frustration. For example, in the words of one participant, “[the technology companies] don’t always listen to the producer, I mean [they think] we are just a bunch of idiots that milk cows, right? So not many people understand how this data [can] help. But I mean, if the company would just [bring me to headquarters] to work with me” (P1). Successful adoption of technologies is predicated on a successful learning process, which is dependent upon collecting information on what the technology can do, integration of the technology into the farm management routine and evaluation of the associated outcomes (Pannell et al., 2006).

Some participants felt that they were not utilizing data to its full potential and that in some cases the data collected were not what they needed to make decisions. Some farmers also perceived an excess of information or information that was difficult to integrate. As one participant explained, after installing a new AMS they were given “like 15 papers, you just kind of you look at them one or two or three times” (P8). In addition, some felt that they did not know which data were most relevant:

You’re always looking [at the data]. You know, everybody looks at something different. My son looks at the daily kilograms, herd average for the cows, and the number of milkings [per cow]. I check more the health aspects ... and the heat [detection]. And my wife looks at the rumination aspect. There’s information up the wa-zoo, you know, and yeah, everybody—like the three of us—looks at something different (P9).
Effect of Technology on the Cow and the Relationship Between Cow and Farmer

Many participants commented on how monitoring technology could be used to assess animal health, and reduce illness and injury: “if you’ve got a cow that’s typically in the robot every, for example, six hours, all of a sudden that’s eight hours since she’s [visited the robot] … I’ll just look okay, when did [she] last eat? Oh, [she hasn’t] eaten all day? So, we’ll have a look at her. [Maybe] she has an upset stomach or a sore foot or something, right?” (P11).

Participants felt that technology was able to detect problems earlier than traditional management allowing them to provide improved care: “So, their eating was [down] before we see the milk drop… and so we would be catching these cows faster to provide them better care, faster treatment… and be healthier” (P3). Previous research has shown that wearable technologies can help detect disease before visual observation (see review by Eckelkamp, 2019). However, some participants argued that the technology could not catch issues as well as they could, given their years of experience: “you’re getting [the cow] up and you’re seeing, you know, there’s one limping or whatever you might not catch her as quick if you’re not getting them up three times a day to bring to the parlor” (P5). One participant emphasized the important role of the farmer as follows:

One of my pet peeves… is that you should still be a cow man, have an eye for cattle and don’t always completely rely on the [AMS] and stuff. You have to be able to judge a cow, OK—this is the reason she’s doing well. [If] she’s not, she’s over conditioned, under conditioned, etc…. Be calm around them and don’t just rely completely on the data (P4).

Our participants commented how the installation of AMS changed how they interacted with their cows. In some cases, this change was viewed as positive but this was not always the case. For example, farmers described that they were no longer able to recognize each of their cows:

As you get older of course, you recognize so and so, and so and so, like certain cows, in their second, third, fourth lactations. I mean, there’s a lot of two-year-olds in the barn, and so I have to look at my phone. Who the hell is that? Wow, she’s given 38 L a day, and I don’t even know who she is (P4).

Previous research has also documented a distancing of human-animal relationships associated with some farm technologies (Wildridge et al., 2020). The implications of this changed relationship extended even to culling decisions; some farmers described that AMS had made it easier for them to cull their animals given that their relationship with individual cows was more distanced:

Eastwood et al. (2016) found that New Zealand farmers wanted more training on how to access relevant data and use customized reports from their technology. Other work has reported that poultry farmers stated that in addition to lack of access to capital, a key barrier preventing them from integrating technology was the lack of extension support (Olaniyi et al., 2008). Our results, when considered along with previous research, suggests that there is opportunity to create more intuitive, user-friendly systems that can summarize key output and link this to clear decision points, such as some smartphone applications (Rathi et al., 2019) and web-based tools (Tedeschi et al., 2021) to support decision-making on-farm.

Lundström and Lindblom (2021) found that dairy farmers were surprised by the amount of computer literacy required after installing new technology, and that many farmers did not know how to interpret the data provided by the automated system. Participants in the current study also expressed the need for reliable support from the equipment supplier to more successfully interact with the new technology: “I don’t think I realized when we started, how important the service [from the supplier] was going to be… Because of course, if a robot goes down, it causes a huge backlog, right? And so, it can’t be down [for] long and that was a big learning curve” (P6). Learning how to use new technology may require the help of trusted advisors and extension agents; Canada does not have an agricultural extension system such as that in the United States, and farmers instead rely upon private services for advice (Milburn et al., 2010). Expanding extension or training services targeted specifically at better understanding how the data can help inform farm management may be an area requiring increased attention.

Adopters of technology are considered to fall into 5 categories ranging from innovators who proactively seek new information, often directly from the manufacturer (see also Lamb et al., 2008), and are the first to adopt new innovations to laggards who only adopt a technology once it is accepted as standard or viewed as a traditional aspect of farming. In the current study we did not categorize participants, but future work might benefit from understanding the different technology uses and perceptions of farmers based on the different categories presented by Rogers (2003).
The other thing I found, too, is that, because I don’t milk them twice a day, I’m not as sentimentally attached to my cows. I’m finding it easier to cull cows in [the AMS] system, because I don’t know them as well as I used to. . . . I [still] find it not pleasant, but easier than it used to be (P4).

The perception that the human-animal relationship changes with the implementation of AMS has been documented by others. A recent study followed the transition of 5 farms from conventional milking systems to AMS and reported that the farmers felt there was little change in basic management practices, but 4 out of 5 farms reported fewer farmer-cow interactions after the transition (Wildridge et al., 2020). Positive relationships between farmers and their animals tend to be highly valued by farmers (Bock et al., 2007) and citizens (Spooner et al., 2014) alike, so future work should seek to better understand how technology may enhance (or interfere) with these relationships.

**Technology as the Future of the Farm**

Technology was discussed as a next step in the farm’s development, for example, to address the problem of outgrowing existing facilities and the need to respond to new challenges for the business. In some instances, current or planned facilities were viewed as incompatible with the adoption of new technology. For example, one participant believed that AMS limited opportunities for growth, in that farms that used parlor milking were able to more rapidly increase cow numbers in response to increased demand:

> So, someone’s gonna have to milk 1,000 cows to make up for all the smaller robot farms and that’s gonna be us. And so, we always cheer [when a new AMS is installed elsewhere] because we know it’s another couple of kilos [of milk quota] that are going to come our way because they won’t be able to fill them all (P1).

Integration of future technology was also discussed in relation to the need for labor. This was particularly in relation to the move to AMS:

> We had a really good long-term milker… excellent, excellent guy… I appreciated the fact that I didn’t have to, you know [get] up at four or five in the morning, and so I kind of got used to that and then with the kids getting more involved in sports, various activities, and stuff, it was nice to have the opportunity to escape from the farm for a few hours here and there. So, I always said to my wife, if our milker ever wants to retire, I’m calling a robot salesman the next day... So then out of the blue, he just decided he wanted to change his career and do something different. . . . Next day I called the robot salesman (P11).

Some participants discussed that, as more technology was integrated onto the farm, it would be necessary to decrease external labor: “The banks, quite frankly, told me, if you’re taking this step [going to AMS], you need to cut your wage bill in half” (P4).

When weighing considerations regarding the adoption of new technology, participants discussed the need for a sound business case to investments in technology. In the words of one participant:

> Number one is cost, but [it] also [has to be] cost effective. So… virtual reality glasses, [they would be] awesome. They’re so cool [and] convenient. But would we see the payback? Some technology like activity monitors, for example, it pays back substantially, not only because you don’t need to run as many programs. . . . it pays back in that your cows not [needing] hormones [injections] (P3).

Research with US farmers has illustrated the importance of purchase cost and the perceived cost-benefit ratio when deciding on a new technology (Borchers and Bewley, 2015). The prospect that costs might decline was sometimes seen as a reason to delay purchases, with the understanding that technology tends to become less expensive the longer it is on the market. As stated by one participant:

> Technology gets better and cheaper all the time. Right? Like, things start off and [initially] yeah, that’s a good idea. But it doesn’t pencil out financially or it’s just not practical or it doesn’t work on the scale you need it to and then eventually, as things get worked through, it gets better or gets cheaper or gets more efficient. So, yeah, there’s always going to be new technologies (P10).

**Farmer Views on Gene-Editing Technology**

Our final aim was to understand farmer views on the use of gene editing. It is worth noting that no participant raised the topic of gene editing before our asking them about this topic, suggesting that this technology was not top-of-mind. Although most of the participants did not specifically address their views on gene editing, they did speak about genetic technologies more generally, often making reference to genomic testing.
Responses arising from this question were coded into 3 themes: (1) accepting the new technology, (2) the commercial adoption of this technology, and (3) uncertainty and unknown factors.

**Accepting of the New Technology.** Gene editing was viewed by some participants as advancement similar to others they had experienced as dairy farmers, considering this be “just a natural next step” (P4). Some participants felt that at least some gene-editing applications (e.g., allowing for the rapid adoption of polled genetics) would be beneficial for the dairy industry, “It would change the industry for the better […] So, let’s just insert the full gene into the bulls we already have. And we’re done. […] literally improved the dairy industry within a year” (P1).

**Commercial Adoption of the Technology.** The discussion around gene editing often focused on the adoption of this technology on farms, with participants varying in whether they saw themselves as potential users. Some participants stated that they would not use gene editing, sometimes because they had simply not yet considered this new technology, and sometimes stating that they would never consider it. As an example of the former, P6 stated that gene editing was simply never discussed: “Genomics, for sure, we talk about all the time. Yeah. Um, gene editing? No, we don’t talk about it” (P6). Others responded that they saw no need for gene editing as they either already had solutions for existing issues that could potentially be solved through gene editing or they felt that it was not accessible. As one farmer stated, “Polled is not really one we … look for, we […] sedate [when dehorning] everything anyways…” (P5).

Some participants discussed their concerns in relation to the challenges associated with groups resistant to this technology. For example, one participant felt that to overcome skepticism around the use this technology further regulation was needed:

> I mean, I think the only skepticism people [have is that they are] just uncomfortable with [gene editing], [it] is probably no different than […] watching a picture of a TV screen or something like this, get on board and go with it. So, I think for those people, let us make sure the right regulation is in place, make sure that the government’s involved in making sure that there is no overstepping [of] boundaries (P1).

Interesting, agricultural professionals in Ireland believed that despite some technologies potentially allowing for more efficient farming practices they were concerned that some of them may generate consumer opposition (Regan 2019). Some work has specifically explored public attitudes to gene-editing livestock, finding that acceptance varies based upon the specific purpose; gene editing intended to provide animal welfare benefits was viewed as more acceptable than that focused on improving productivity (Ritter et al., 2019; Yunes et al., 2021).

**Uncertainty and Unknown Factors.** Many participants were reluctant to discuss gene editing, in part because of uncertainty about the risks. One farmer stated: “I do have concern about it. I feel like it’s a little bit of like a Dr. Frankenstein kind of a scenario like you don’t know what you’re creating” (P1). Another farmer stated that they liked some of the specific applications of gene editing (i.e., the genetic insertion of the polled gene), but were less positive about applications intended to achieve general benefits to production:

> If you’re gonna start gene editing, polled, I think is an easy one, you just have something out, you know, like, you can take a little snip out, so there’s no more horns. Hopefully, you don’t take out anything that you shouldn’t. […] But to gene edit to get a more productive animal. Like, you’re messing with a lot to get there […] I don’t mind that they look into it. But I have just some concerns. And I would probably like, for a lot of other technology, I don’t mind being the first in, but with gene editing, I’m way more skeptical. Like, I just I just think you’re trying to make a puzzle, but you don’t even know what all the pieces are (P2).

Skepticism associated with implementation of gene-editing technologies was often discussed in terms of trade-offs. For instance, one farmer felt that despite potential benefits in terms of milk production they were concerned that using gene-editing technologies may jeopardize consumer trust. In their words:

> But my only concern with that sort of thing is consumer perception, right? …people get into their heads that this stuff is bad. Oh, you’re manipulating the cow and it’s not real anymore. You know, from a productivity point of view. I mean, there’s all kinds of possibilities there but we want to make sure that consumers are happy that we’re looking after the cows properly, like with all the welfare issues and that sort of thing (P11).

**Study Limitations**

The current study has several limitations. We used a convenience sample of dairy farmers from Western
Canada; our results should be interpreted in relation to the specific context of these farms. One potential limitation is that we did not ask farmers to define what they meant when they used the term technology; a decision that no doubt contributed to the broad use of the term by our participants. Given that many farms in this region had adopted or were considering the adoption of AMS (Tse et al., 2018), it is not surprising that many participants focused on this technology. We also focused only on the interview participant, and how they perceived the technology, and less on understanding the dynamics between employees and other persons on the farms, when relating to the use of the chosen technologies. We encourage future work to broaden the scope of interviews to capture some of these aspects, such as how employees were trained, how the involved staff and managers of the farm used the technology in their joint efforts to care for the cattle, and how it was received by different persons connected to the management of the herd. We encourage future research to investigate how farmers interpret the term technology in discussions, particularly given the wide variation in definitions of the word technology (Wahab et al., 2012). Our use of virtual interviews (due to the COVID-19 pandemic restrictions) restricted the use of the timeline mapping activity, and may have reduced rapport between the interviewer and participants. The virtual interview format may have also been more challenging for some of participants than others, which may have contributed to some of the interviews being much shorter than others. That said, previous research has shown that Zoom allows for the collection of high quality data compared with other approaches (Archibald et al., 2019). With regards to the questions about gene editing, many interpreted our question more broadly and spoke about genomics, perhaps because participants were largely unfamiliar with this technology. The lack of quality responses to this question may have contributed to our failure to reach data saturation. However, our work on this aspect provides a starting point for others, and thus we strongly encourage future work to continue working on farmer attitudes to these types of up incoming technologies to gain a more in-depth understanding of their views.

CONCLUSIONS

New technology can result in role changes for farms and affect how farmers interact with their animals. Participants in the current study viewed technology as an integral component of their farming system but voiced concerns about some technologies falling short of expectations. Participants did not raise gene editing as a top-of-mind technology, but when prompted some indicated their acceptance and others more reluctant to embrace the method.

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