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# *Symposium review:* Considerations for the future of dairy cattle housing: An animal welfare perspective*

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## ABSTRACT

Many contemporary dairy cattle housing practices are at odds with societal perceptions of positive animal welfare. The public (i.e., those external to the dairy industry) typically emphasizes the importance of naturalness for dairy cattle, such as through provision of pasture, freedom of movement, and the ability to interact socially with conspecifics. Yet, in the United States, the majority of lactating dairy cattle are reportedly housed without any access to pasture, and almost 39% of dairy farms use tiestalls, which restrict movement and social interactions. In addition to being in conflict with public expectations, a lack of pasture access and restrictive housing systems are also in conflict with the animals' own motivations, which can adversely affect their welfare. For example, dairy cattle are highly motivated to access pasture and show a reduction in oral stereotypies when allowed on pasture after periods of tethering. Calves housed without social contact have cognitive deficits and exhibit increased fear responses to novelty. We argue that the long-term sustainability of the dairy industry will depend on the extent to which housing systems reflect public concerns and the animals' priorities. The adoption of technologies, such as automated feeders and remote monitoring systems, may represent a means to practically promote the animals' natural behavior while simultaneously improving individualized care. Although older generations of the public may consider technological solutions to be a further deviation from naturalness and a departure from dairy farming's agrarian roots, the definition of "naturalness" for younger generations may well have expanded to include technology. As the buying power shifts to these younger generations, the adoption of technologies that promote natural cattle behaviors may be one means toward reconciling the disconnect between public perceptions of animal welfare and contemporary dairy farming practices.

**Key words:** natural living, pasture access, tiestall, millennial

## INTRODUCTION

There is a misalignment between many contemporary dairy industry practices and societal perceptions of what constitutes good animal welfare (Weary and von Keyserlingk, 2017). In part, this misalignment centers on the public's desire for naturalness for farm systems (Lassen et al., 2006), including the provision of pasture, freedom of movement, and the ability to interact socially with conspecifics. As such, the cited absence of naturalness is commonly reflected in the ways in which dairy cattle are housed. In a systematic review of public attitudes toward farm animal welfare and disease, housing represented the most researched and discussed topic (Clark et al., 2016). Just as naturalness is prioritized among the public, the fulfillment of a caretaking role, in pursuit of improved health and productivity, is continuously of great importance to stakeholders within the farming community (Kauppinen et al., 2010). Thus, housing practices such as tiestalls, lack of pasture access ("zero-grazing"), and individual housing of calves are likely perceived by the public as unnatural, but may be perceived by the farming community as providing a high level of individual animal care in addition to increased practicality and improved economic feasibility (von Keyserlingk et al., 2009).

An animal's ability to live a reasonably natural life through the expression of highly motivated, natural behavior is of critical importance to animal welfare (Fraser et al., 1997). Although the definition of "natural behavior" for a domesticated species such as dairy cattle may not be clear, research methodologies that measure animal preferences and motivations for the expression of certain behaviors (e.g., grazing, social contact) can

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provide insight into which behaviors are important to dairy cattle. Research has shown that housing practices that limit natural behavior expression are not only incompatible with public perceptions, but also with the animals' own priorities. In this review, we will further explore the perspectives of 3 key stakeholders: nonindustry citizens (the public), the farming community, and the animals themselves. We then suggest reparations for this fissure, potentially through the continued adoption and widespread use of technologies. Existing and emerging agricultural technologies have the potential to improve the health and individualized care of animals (a priority of the farming community) in addition to promoting natural behavior expression (of importance to the public). In leading to better health and an enhanced behavioral repertoire, these technologies also have the potential to improve the affective state of the animal, thereby enhancing overall welfare.

## THE MISALIGNMENT

When asked to envision an ideal dairy farm, US citizens unaffiliated with the dairy industry (n = 468) commonly responded that cows should be provided with space to "roam" (Cardoso et al., 2016, p. 1664). Participants had broad consensus that this roaming space should be outside; as one participant stated: "on pasture where the cow could be free" (p. 1664). Other studies have also confirmed citizens' emphasis on pasture access and freedom of movement; in Schuppli et al. (2014), 83.9% of 316 participants unaffiliated with the dairy industry responded affirmatively to the question "Should dairy cows be provided access to pasture?" (p. 5186). Growing evidence suggests that the public associates pasture access with positive animal health and welfare (see Boogaard et al., 2008; Ellis et al., 2009; Boogaard et al., 2010; Miele et al., 2011), and that many oppose zero-grazing systems (approximately 81% of 200 Brazilian citizens, Hötzel et al., 2017).

The public's emphasis on social interactions for dairy cattle (Schuppli et al., 2014) represents another key emergent theme. This theme is echoed in Widmar et al. (2017), where the ability to interact socially with other animals was ranked as having the most positive effect on the welfare of dairy cattle (among a representative sample of 1,200 US residents). Participants in Cardoso et al. (2016) also alluded to the importance of social interactions, expressing the desire that cows and calves remain together after parturition. Early cow and calf separation is known to be a contentious issue worldwide; in one study, 130 of 200 Brazilian citizens opposed the practice (Hötzel et al., 2017). The primary reasons provided by the participants in support of keeping cows and calves together included naturalness (cited by over 30% of participants), animal welfare, importance of early contact, and ethical concerns (Hötzel et al., 2017).

As a counterpoise to the public's emphasis on naturalness, people within the dairy industry (e.g., dairy farmers, dairy scientists, veterinarians, and agricultural advisors) often focus on optimizing health and biological functioning (von Keyserlingk et al., 2009; Cardoso et al., 2019). The prioritization of health is not exclusive to dairy farming and is evident throughout the agricultural community. For instance, "taking care of the animals' health" was ranked as an important factor among both Finnish pig and dairy farmers (Kauppinen et al., 2010; p. 526), and similar views were echoed among Dutch pig farmers (Benard and de Cock Buning, 2013), meat livestock farmers in the Netherlands (Te Velde et al., 2002), and Flemish broiler producers (Tuyttens et al., 2014).

Although producers frequently describe taking an active role in caretaking and ensuring animal health, they on occasion refer to humane treatment and affective state (e.g., the emotional lives of the animals; Kauppinen et al., 2010). The discussion of affective state, however, is commonly framed in terms of production; for example, farmers from the Kauppinen et al. (2010) study offered statements such as "If the animals feel great, they are productive..." and "when an animal feels well ... of course it will stay healthier and grow well" (p. 530).

The perspectives on naturalness and natural behavior among the farming community are still poorly understood, and are likely to be variable and complex (Sumner et al., 2018). In support of this complexity, de Rooij et al. (2010) uncovered a variety of viewpoints among Dutch dairy farmers that could be classed within several ethical frameworks, including one that positions animals and their natural behavior as a focal point for developing and refining their housing practices. This framework of naturalness partially represents the viewpoints expressed by some Canadian and US dairy farmers, veterinarians, and industry professionals (see Schuppli et al., 2014), of which the majority (59.6%) supported pasture access for dairy cattle. Yet, given the predominance of zero-grazing systems in the US and Canadian dairy industries today (Denis-Robichaud et al., 2016; USDA, 2016a), there is an apparent conflict between support for pasture access and the perceived ability to enact it in practice. Conversely, some groups within the agricultural industry (e.g., the Dutch pig producers in Benard and de Cock Buning, 2013) do not see natural behavior as a critical aspect to positive animal welfare. The opinions of other industry stakeholders, such as veterinarians, also vary considerably depending upon region; for instance, Canadian veterinarians participating in a focus group study spoke in support of cow and calf separation (Sumner and von Keyserlingk, 2018), but this position was not typically favored by Norwegian veterinarians (Ellingsen et al., 2012). Even within region and within farming groups, variation exists in the conceptualization of naturalness and its importance to animal welfare; in one study, organic dairy farmers in Scandinavia provided differing perspectives when queried about natural living for dairy calves (Vetouli et al., 2012). Farmers in this study gave a range of responses as to why natural living was important for calf welfare, including that it promoted better health, was critical for consumers, or was simply "the way it should be" (p. 357). Yet farmers disagreed on the extent to which natural living was even possible within a production system, and which living conditions were important to promote it (e.g., outdoor access, socializing, cow-calf contact, and so on).

The views of the public are similarly nuanced. Although citizens tend to frame their concerns in terms of naturalness, they maintain an awareness of other welfare constructs including health and biological functioning. Animal health has been identified as a key factor in citizens' conception of welfare for a variety of production animal species (e.g., pigs and fish: Frewer et al., 2005; dairy cattle: Cardoso et al., 2016). When asked to envision the ideal dairy farm (Cardoso et al., 2016), many of the US participants frequently offered statements addressing cattle health, suggesting, for example, that cows should be "clean, free of disease and [have] good medical care" (p. 1666). In another study (Cardoso et al., 2018), US participants were surveyed on their attitudes toward housing scenarios that varied in terms of naturalness (pasture vs. indoor housing) and affective states (presence or absence of heat stress). Although participants were more favorable overall toward pasture versus indoor housing, they rated indoor housing with ventilation (barn fans that mitigated heat stress) more favorably than pasture without access to shade (i.e., increased risk of heat stress). Thus, citizens appear to favor naturalness for dairy cattle, but not at the expense of health or positive affective state. In contrast, preservation of health at the expense of natural behavior is usually not supported by the public (Clark et al., 2016). Citizens largely recognize that farms must be profitable (dairy: Cardoso et al., 2016; pigs: Sato et al., 2017), but they place less emphasis on this theme compared with producers and agricultural advisors (Cardoso et al., 2019).

In the subsequent sections, we review several of the aforementioned themes commonly referenced and prioritized by the public, specifically: space to roam, including pasture access and freedom of movement, and the ability to engage in social interactions. We will address each of these themes in light of contemporary dairy cattle housing practices, research results addressing the animals' own perspectives, and potential avenues toward stakeholder consensus.

## Space to Roam

***Pasture Access.*** Recent USDA (2016a) data suggest that 7.5% of US dairy operations report using pasture as the primary housing type for their lactating cows, and over 80% of all lactating dairy cattle in the US are housed in zero-grazing systems (i.e., without access to pasture). The proportion of nonlactating (dry) dairy cattle allowed on pasture is higher, at 34.0% (USDA, 2016a). Organic herds must be provided with at least 120 d of pasture grazing per year, in addition to year-round access to the outdoors (USDA, 2013), yet these herds account for only 7.4% of US farms (USDA, 2016a). In Canada, much less information is available on pasture access for dairy cattle. Denis-Robichaud et al. (2016), in their survey on reproductive management practices in Canada, asked one question about access to pasture. Of the 832 farms that responded (representing 7% of total farms in Canada in 2014), 75% of the respondents reported employing zero-grazing management, 18% reported providing access both night and day to pasture, 4% at night only, and 2% limited daytime pasture access but only during the summer. Taken together, these statistics indicate that the majority of dairy cattle in the United States and Canada do not have regular pasture access.

A review by Arnott et al. (2017) identified notable animal welfare benefits associated with pasture access compared with continuous indoor housing, including decreased levels of lameness, hoof and hock lesions, mastitis, and mortality. Behavioral benefits, including grazing, improved resting times, and fewer aggressive interactions, were also enumerated. Negative energy balance, however, tended to be more severe in pasture-based systems, and pasture access alone may be considered insufficient if it does not provide opportunities for the animals to seek shelter. Participants in Schuppli et al. (2014) had favorable attitudes toward pasture but clarified that cows should have "shelter from the wind and sun and rain" (p. 5188). Dairy cattle preference for pasture is highly influenced by time of day (Legrand et al., 2009), humidity, temperature, and rainfall (see Charlton and Rutter, 2017), and thus parallels the public's concern that cattle be protected from harsh weather conditions (Cardoso et al., 2018). Open lots can also provide roaming space, but in the absence of shelter or cooling systems, the welfare of dairy cattle is likely to be impaired during inclement weather or periods of high temperature-humidity index (see review by Fournel et al., 2017). Depending upon climate and region, silvopastoral systems (a form of agroforestry in which trees, forage, and pasture for livestock are integrated) can provide animal welfare benefits in addition to ecosystem services (Tarazona Morales et al., 2017). This type of system is likely to be attractive to the public based upon high levels of naturalness, and cattle housed in these systems compared with a monoculture system have demonstrated more stable social hierarchies and increases in positive social behavior (Améndola et al., 2016).

Research suggests that cattle are highly motivated to access pasture; von Keyserlingk et al. (2017) found that cattle were willing to push comparable amounts of weight to access pasture and fresh feed. As the motivation to obtain fresh feed after milking represents a benchmark for inelastic demand (Dawkins, 1988), the strong motivation of cattle to access pasture matches, if not exceeds, the public's strong support for implementation of this housing type.

The predominance of zero-grazing systems in North America may be attributed to an ability to better monitor the nutrient intake of animals via formulated diets, increased milk production, increased automation, or lack of cost efficiency from grazing the land. Cattle housed continuously on pasture have been reported to produce less milk (Hernandez-Mendo et al., 2007). Soriano et al. (2001) also reported less milk production and reduced TMR intake when cows were provided access to pasture for 8 h/d after milking. In contrast, Chapinal et al. (2010) found that overnight pasture access did not result in reduced milk production or TMR intake. Therefore, if continuous access to pasture is not feasible from a management perspective (e.g., due to geography, weather conditions, land scarcity, or lack of year-round quality pasture), partial access at certain times of day or night, or the provision of outdoor loafing areas (Smid et al., 2019), may represent more manageable alternatives. As agency is an important element to positive welfare in a variety of animal species (Špinka and Wemelsfelder, 2011), providing animals with the choice to access pasture represents a potential housing refinement that resonates with public opinion [e.g., in Schuppli et al., 2014: "give them a choice…let both options be available…" (p. 5188)].

***Freedom of Movement.*** The use of tiestall housing is still common in North America. Approximately 39% of US dairies and 74% of Canadian dairies use tiestall barns as their primary housing (USDA, 2016a; CDIC, 2018). It has long been known that tiestall housing, in which animals are typically tethered to individual stalls, alters dairy cattle lying patterns and increases the number of lying interruptions, the number of unfulfilled intentions to lie down, and the time spent kneeling (Krohn and Munksgaard, 1993; Jensen, 1999). More recent research echoes these findings, detailing abnormal lying patterns in tiestall systems (e.g., Plesch et al., 2010; Enriquez-Hidalgo et al., 2018; Shepley et al., 2019). Thus, from the cow's perspective (as well as from the public's; Robbins et al., 2019), the expression of certain natural behaviors is hindered.

A large proportion of tiestall farms in the United States (73%) provide pasture access for at least part of the year (USDA 2016a), whereas this proportion is smaller in Canada (15%, Denis-Robichaud et al., 2016). Very limited evidence is available from a welfare perspective addressing how this level of compensation compares to year-round indoor housing in freestalls (but see Seo et al., 2007; Veissier et al., 2008); any benefits of pasture access will likely depend upon the frequency, duration, and quality of outdoor access. In any case, when dairy cattle are to be housed in tiestalls, regular access to exercise areas improves both natural behavior expression (Krohn, 1994) and health (Regula et al., 2004; Popescu et al., 2013).

Even when housed in more open systems, such as freestall barns that allow animals to move about the pen, cattle may have limited space to roam, particularly since overstocking is common in North American dairy herds. One study of 121 North American freestall dairies identified 60% of herds with stall stocking percentages above 100% (von Keyserlingk et al., 2012). Research has also shown that the public is concerned over lack of space and high stocking densities as potential catalysts for stress and disease (Schuppli et al., 2014; Clark et al., 2016). Indeed, overstocking is known to have negative welfare implications for dairy cattle, including reduced lying and resting times (Fregonesi et al., 2007), and increased competition for feed (Collings et al., 2011) and stall space (Winckler et al., 2015). The rate of agonistic behaviors at the feedbunk has been shown to increase alongside stocking densities (Proudfoot et al., 2009). Additionally, consistency in social group composition can reduce competition and provide dairy cattle with behavioral and health-related benefits (Proudfoot et al., 2018).

The public is, in general, concerned about the intensification of farming practices (Spooner et al., 2014); the current trend in increasing herd sizes represents a perceived disconnect from naturalness, which some consumers associate exclusively with small-scale family farming (see Gieseke et al., 2018). Gieseke et al. (2018) has suggested that herd size is not a reliable indicator of animal welfare, with management and housing practices making a more substantive contribution. Mortality rates have been reported to increase alongside increasing herd sizes, which is potentially attributable to a reduction in individual animal monitoring in larger herds (Shahid et al., 2015). Conversely, dairy farms with larger herd sizes are more likely to adopt precision technology (Gargiulo et al., 2018). Such technology could actually lead to increased individual animal monitoring, thus highlighting the complexity of the issue. In reality, the association between herd size and welfare is influenced by numerous variables, such as the skills and training of farmers and personnel, the herd facilities, and animal-to-caretaker ratios (Barkema et al., 2015).

### Ability to Interact Socially

It is common practice in North America to separate dam and calf within 24 h and house calves individually through weaning (Vasseur et al., 2010), which stands in contrast to the public's emphasis on the value of social interactions between conspecifics (Widmar et al., 2017), including between dam and calf (Ventura et al., 2016a; Hötzel et al., 2017). From the calf's perspective, individual housing can lead to increased weaning distress (De Paula Vieira et al., 2010), increased fear responses and neophobia (Jensen et al., 1997; Veissier et al., 1997), reduced solid feed intake before weaning, and even cognitive deficits (Meagher et al., 2015) compared with social housing. Pair housing represents a simple and cost-effective method to counter some of the negative effects of individual housing on calf health and behavior (Bolt et al., 2017). Compared with individually housed calves, pair-housed animals have shown increased concentrate and solid feed intake (De Paula Vieira et al., 2010), increased average daily weight gain (Costa et al., 2015), a higher level of behavioral flexibility (Gaillard et al., 2014), and decreased fear responses (Jensen and Larsen, 2014). There appears to be no consistent relationship between housing type (group vs. individual) and calf health outcomes (see review by Costa et al., 2016), although few studies have addressed health outcomes in pair versus individual housing systems specifically.

From the dam's perspective, natural maternal behavior includes a high number of suckling bouts within the first week postpartum, and affiliative interactions such as reciprocal allogrooming between the dam and her calf (Vitale et al., 1986). Although increasing the acute distress response to eventual separation, cow-calf rearing is associated with reduced mastitis rates in the dam (see review by Beaver et al., 2019a) and beneficial long-term effects for the calf, including a broad range of social and exploratory behaviors and a decrease in oral stereotypies (see review by Meagher et al., 2019). Proponents of immediate separation argue that cow-calf rearing can have negative consequences for calf health and cow milk yield, but there is little evidence to suggest that a period of suckling impairs calf health or results in decreased whole-lactation milk yield (Beaver et al., 2019a; Meagher et al., 2019, respectively). More research is required to optimize cow-calf housing systems, particularly toward the development of best practices to mitigate distress responses to eventual separation. Specifically, further investigation is needed into fence-line weaning systems (Price et al., 2003; Stěhulová et al., 2008), uddernets (Johnsen et al., 2015a,b), temporary separation (Pérez et al., 2017), and the provision of additional milk sources during the dam-rearing phase (Johnsen et al., 2015b).

In a recent review, Proudfoot (2019) addressed the design of maternity spaces and concluded that the ideal maternity space should permit expression of a cow's natural maternal behavior, including the ability to seek an isolated space before calving. Approximately 59% of dairy herds in the United States house multiple animals in calving areas, and 39% do not have maternity housing separate from lactating cows (USDA, 2016a). Therefore, in some of these instances, it may be beneficial to provide access to a barrier or some type of hiding space where the cow can seek partial seclusion from her herd mates (Proudfoot, 2019). Individual maternity pens have been associated with reduced disease risk in numerous studies (including Svensson et al., 2003 and Pithua et al., 2013); however, keeping cows in individual housing for long periods of time (i.e., more than a few days) before calving may also be a stressor (Munksgaard and Simonsen, 1996) due to lack of social interactions (Boissy and Le Neindre, 1997).

For adult cattle in tiestall barns, the ability to interact with conspecifics is limited; cattle can only physically interact with their immediate neighbor(s), and other social interactions are restricted to vocalizations (Gavojdian et al., 2009). The social components of estrous behavior, which include mounting, sniffing, chin resting, licking, and head butting (Roelofs et al., 2010), are also prevented by tethering. Importantly, the ability to interact socially should include the ability to disengage from such interactions when necessary, and avoiding negative social interactions may not be possible in tiestall barns or overstocked facilities.

Although we cannot provide an exact blueprint for future dairy cattle housing, we recommend, at minimum, that barns should not be overstocked, freedom of movement should be provided, cattle should have the opportunity to access the outdoors, and the cow's own preferences and motivations should be given strong consideration.

## EDUCATING THE PUBLIC

The discord between industry and public stakeholders is further amplified if reductive arguments are employed on both sides of the debate; the public has sometimes classed producers as being overly focused on production (see Sumner et al., 2018), whereas the farming community has been known to dismiss the public as being misinformed or ignorant of rationales underlying management decisions (Benard and de Cock Buning, 2013). Some evidence suggests members of the dairy farming community believe educational efforts would pay large dividends in achieving public support and counteracting negative perceptions of the industry (see Croney et al., 2012). However, the literature also indicates that one-way instructional efforts aimed at educating the public about dairy farming practices are not likely to be effective. In fact, one-sided educational efforts and the provision of additional information have, in some instances, served to reduce public support. For example, when North American and Brazilian citizens were provided with further knowledge about various housing options for gestating sows, they became less accepting of gestation crates than when initially queried (Ryan et al., 2015; Yunes et al., 2017; respectively). Hötzel et al. (2017) solicited the views of the Brazilian public on practices of dairy cow and calf separation and zero-grazing. Beyond uncovering a low level of public support for these practices, the researchers reached 2 important conclusions: that neither previous awareness of the practices nor the provision of additional information increased support. On the contrary, when participants were given information, they *more* often rejected the implementation of these practices on dairy farms (Hötzel et al., 2017). Ventura et al. (2016a) also found no relationship between prior knowledge and attitudes toward farming practices; following a visit to a dairy farm, many participants became *less* confident that dairy cattle led a good life (42% confident before the visit compared with 24% after the visit). Finally, in a systematic review of public attitudes, Clark et al. (2016) reported that those with higher education levels, increased familiarity with farm management practices, and more frequent farm visits, voiced *more* concern regarding modern conditions for farm animals; participants expressed the opinion that current practices must change and that suitable alternatives were required (Clark et al., 2016).

We argue that, when envisioning the future of dairy cattle housing, both the public's and the animals' perspectives should be integrated with those of the farming community. Dismissing public concern as ignorance or resorting to one-way educational efforts may result in further erosion of public support that could become counterproductive toward addressing the needs of animals on farms. Two-way engagement with consumers and citizens, rather than education, is perhaps a more constructive approach. For example, Weary and von Keyserlingk (2017) encourage an "open house" framework as a method of 2-way engagement, in which mutually beneficial conversations between farmers and citizens can occur, ideally resulting in a "cycle of continuous improvement" (p. 1204).

## THE FUTURE OF DAIRY CATTLE HOUSING

### *The Role of Technology*

The future of dairy cattle housing requires a holistic approach that incorporates input from 3 key stakeholder groups: the industry, the public, and the animals themselves. From the animals' perspective, certain behaviors are more critical than others, and evaluation of animals' priorities, via continued ethological research, is necessary to develop constructive housing improvements. Notably, the distinction between "natural behavior" and "natural living" can be harnessed to incorporate cattle's natural behaviors into housing environments without the requirement of natural stimuli (Beaver et al., 2019b). That is, adoption of modern technology, which arguably deviates further from "natural living" in the purest sense, may actually facilitate natural behavior expression for animals without also providing completely natural environments.

Automated calf feeders present an excellent example of the distinction between natural behavior (e.g., suckling) and living in a natural environment (e.g., living on pasture with the dam). Although the modern appearance of automated feeders may not evoke feelings of naturalness to the same extent as an image of a dairy calf suckling the dam, these automated feeders can promote natural behavior in calves. In the first week after birth, calves in nature nurse the dam between 8 and 12 times per d (Vitale et al., 1986) and exhibit a strong need to suckle (Hammell et al., 1988). Thus, compared with the common practice of feeding calves a restricted amount of milk [usually 2 quarts (1.89 L) by bottle or bucket 2 times per day; USDA, 2016a] automated calf feeders can better mimic the calf's natural feeding patterns with an unlimited number of visits per day, a higher milk allotment, and the ability to suckle an artificial teat. Of course, automatic calf feeders afford the additional benefit of individual animal monitoring (e.g., see Sutherland et al., 2018) and can therefore be used toward providing the individualized care and improved health that is central to producers and veterinarians. Therefore, when considering the framework of animal welfare proposed by Fraser (2008), we argue that the use of certain technologies can improve both health outcomes and natural behavior expression in animals. Both of these elements can act in tandem to promote positive affective state, leading to welfare improvements.

## The Public's Evolving Definition of Naturalness

As discussed, the adoption of smart technology can incorporate the needs of industry members as well as the behavioral needs of the animals themselves, but what about the public? The public prioritizes naturalness for farm animals, but a gap exists in the literature as to (1) how the public defines "naturalness" in relation to agricultural production systems, (2) how this definition differs across generations, and (3) what extent technology is permissible within the confines of "naturalness."

Older generations, such as Baby Boomers (defined for this purpose as those born between 1946 and 1964) and Generation X (those born between the 1965 and 1980) show interest in new technology (see review by Gaul and Ziefle, 2009) but are generally hesitant to adopt technology compared with younger generations (e.g., Arning and Ziefle, 2007). Reasons surrounding this hesitancy are likely attributable to less computer knowledge and less familiarity with complex technology. Thus, older generations may view "naturalness" in agriculture as animals living outdoors in more agrarian conditions, without technological intervention.

Compared with older generations, younger generations, such as Millennials [i.e., Generation Y, defined as individuals born between 1980 and 2000 (Cavagnaro et al., 2018)] and Generation Z [those with birth years beginning in the mid 1990s (Berkup, 2014)] have come of age with unparalleled access to technology. Much effort has been dedicated to using technology to cater to this demographic. Numerous studies detail strategies for this engagement by advocating for the incorporation of technology into learning environments (Blue and Henson, 2015; Shatto and Erwin, 2017; Au-Yong-Oliveira et al., 2018), the workplace (Canedo et al., 2017), and even as a recruitment method for research participation (Dalessandro, 2018). Thus, there seems to be a consensus that routine use of technology is a "natural behavior" for millennials and subsequent generations. This characterization is confirmed by millennials themselves who identified technology use as the defining feature of their generation (Cisco, 2011). Moreover, one-third of college students reported that the Internet was as important as food and water, and over half elected to relinquish their sense of smell or taste over their smartphones (Cisco, 2011; see review by Stewart et al., 2017). If technology has been incorporated into the state of naturalness for millennials and subsequent generations, it may also be part of their own definition of naturalness as it pertains to the world around them, including agricultural systems.

Millennials have recently surpassed baby boomers as the largest generation in the current workforce (Pew Research Center, 2018a); however, as boomers are the largest population of eligible voters in the United States, they retain and exert a high amount of economic and political influence (Pew Research Center, 2018b). Boomers, classed as having a higher degree of active consumerism than their predecessors (Leach et al., 2008), are skilled at voicing their opinions, but their influence will be overshadowed by the next generation.

We hypothesize that younger generations may indeed have a different definition of naturalness that incorporates technology. Some evidence in support of this hypothesis can be derived from Cardoso et al. (2016), in which the majority of participants (approximately 69%) were millennials. Several respondents referenced modernity, with elements such as "top of the line pasteurization equipment" (p. 1668) representing essential characteristics of their ideal dairy farm. Their views commonly reflected an amalgamation of the industrial and agrarian agricultural prototypes (Fraser, 2008). That is, participants generally associated good animal welfare with higher degrees of naturalness (e.g., access to pasture and limited use of antibiotics), yet clarified that farming should not return to its agrarian roots when it was less profitable and did not harness the use of beneficial technology (in line with Boogaard et al., 2010). Thus, as the buying power shifts to younger generations, the use of technology in dairy farming may become more permissible to consumers of dairy products.

Of course, there is likely to be vast intra-generational variation in individual perspectives of technology, influenced by age, upbringing, socio-economic status, and region. For example, some evidence indicates that younger generations may *not* be more open to biotechnology nor to technology that directly alters the food that they consume [e.g., genetically modified organisms (Tenbült et al., 2005), or shelf-life extension technology (Cavaliere and Ventura, 2018)], although others have found that food naturalness is more important to older compared with younger consumers (see review by Román et al., 2017).

## Technology in Dairy Cattle Housing and Management

New technologies are already becoming rapidly integrated into agricultural systems and have altered the standard ways in which dairy cattle are housed. For example, automated milking systems (**AMS**), which were introduced in the late 20th century, are now used on many commercial dairy farms; as of 2014, 5.6% of Canadian farms used AMS, and this number has increased to 11.5% in 2018 (CDIC, 2018). In the United States, the current figure appears to be considerably lower, at 1.6% (USDA, 2016b), but with the challenges surrounding the historical use of undocumented workers in the United States (von Keyserlingk et al., 2013) the use of AMS will no doubt increase in the coming decade. Radio-frequency identification tags are also routinely used in tracking individual animals within Canadian herds; however, as of 2014 (USDA, 2016a) only 6.2% of dairy operations in the United States employed up-to-date radio-frequency identification technology (corresponding to approximately 20% of cattle).

In a systematic review of sensing technologies and smart computing, Jukan et al. (2017) described the potential for next generation communication systems to enhance farm animal welfare. One main advantage of smart technology is that it is not isolated but, rather, networked. That is, physical devices may be paired with computing systems for data processing. For example, with respect to housing systems, technologies are in development to monitor the health of cattle remotely (e.g., Warren et al., 2003); these technologies are particularly useful because they facilitate the use of pasture access by permitting opportunities for cattle to express natural grazing behavior while obviating the need to bring animals into the barn for routine health checks.

As argued by Jukan et al. (2017) and Barkema et al. (2015), much of the potential for smart technologies to improve animal welfare is untapped, as these technologies are not yet available via some type of centralized system; thus, information is not yet sharable across a wide network. The creation of a data hub would not only benefit the dairy industry through accessible dairy-specific technology but also by harnessing and adapting technology created for other industries and species. For instance, climate control systems in pigs (Congguo et al., 2010), chickens (Ammad-Uddin et al., 2014), and cattle (Sarangi et al., 2014) could likely be further optimized for information transfer through some type of integrated cloud-based system. Moreover, technologies developed for use in companion animals or wildlife could also be practically applied in agriculture. For example, Valentin et al. (2015) have proposed a monitoring system in which health data are transmitted from jackets worn by dogs. This type of technology, if adapted to a neck collar or contained within an ear tag, could be particularly useful for monitoring calves on pasture to permit extended cow-calf contact. Similarly, drones or global positioning systems (e.g., Trotter et al., 2010; Barbedo and Koenigkan, 2018) may be promising for animal monitoring on pasture and potentially for tracking cow-calf pairs.

Importantly, the majority of new technology being developed for agricultural systems is geared toward health and biological functioning. Although this aspect of welfare is critical, little new technology is aimed at assessing natural behavior or affective states. Many technologies are already in use in the dairy context that can be harnessed to study behavior (see review by Rutten et al., 2013), but behavior has largely been treated as a tool to evaluate current or future health outcomes rather than as a primary outcome measure. For instance, the ZigBee sensor can detect cattle movement wirelessly, but its implementation has focused on estrus detection (Li et al., 2010) and other physiological parameters (Kumar and Hancke, 2015). These assertions apply predominantly to animals used in food production, as technologies have been proposed for companion animal species that, for example, are aimed at improving the human-animal relationship (**HAR**) or understanding the ways in which companion animals interact with the world (e.g., Lemasson et al., 2013 through the use of smartphones attached to a dog's back). Since the HAR has been shown in numerous studies to influence the welfare of both calves and adult cattle (Raussi, 2003), this type of technology could be useful in dairy systems as well. The implementation of technical solutions could also result in an indirect improvement of the HAR, simply by relieving farmers of routine tasks and shifting the nature of human-animal interactions. For instance, a recent study illustrated improvements to the HAR associated with transition from conventional milking systems to AMS (Wildridge et al., 2020), including reduced avoidance distance and decreased stress response to handling. The authors attributed this shift to the decreased in milk harvesting tasks, and a consequent reshaping of farmer-cow interactions.

Several hurdles must still be overcome before many of these smart technologies can become mainstream in dairy production systems. For one, the discussion of smart technology is arguably incomplete without an acknowledgment of the economic burdens that may hinder adoption on farm. Technical issues must be resolved (such as those relating to battery life and network connectivity) before many promising technologies become low-cost or cost-effective investments (Jukan et al., 2017). Future dairy cattle housing developments will need to continue to integrate new sensing technologies and smart computing devices as they are optimized and become commercially available. Such technology, while deviating further from naturalness in the purest sense, has the potential to mediate the needs of different stakeholders by facilitating cattle's natural behavior expression while maintaining the high level of health and individualized care (e.g., see Svensson and Jensen, 2007; de Mol et al., 2013) that is central to industry personnel.

## CONCLUSIONS

Many current housing practices for dairy cattle are not consistent with public values and expectations surrounding natural living. In addition to being at odds with public expectations, many of these practices are also in conflict with the animals' own motivations, which can have negative welfare consequences. Cattle themselves can be viewed as important stakeholders in future housing refinements, and further research into their preferences and motivations can yield important information for the incorporation of natural behavior expression into housing systems. The continued adoption of technology could represent a means of repairing the fissure between the needs of the public, the animals, and the farming community by maintaining and improving the high level of individualized care while incorporating opportunities for natural behavior expression in cattle. Some evidence suggests that the definition of naturalness is shifting across generations to include technology, which can only aid in achieving a compromise between stakeholder priorities.

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