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# Public perceptions of potential adaptations for mitigating heat stress on Australian dairy farms

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## ABSTRACT

Temperature variability resulting from climate change poses challenges around the world for livestock production and the welfare of the animals in these systems. As animal industries attempt to combat these challenges, it is vital to understand how potential changes implemented by farmers resonate with societal values. The aims of this study were to determine how different proposed changes to mitigate heat stress in dairy cattle influence public perceptions toward Australian dairy farm systems, including perceptions of (1) cow welfare, (2) confidence in the industry, and (3) trust in farmers. Participants were presented with 1 of 4 treatments representing a potential solution to mitigate heat stress in dairy cattle: (1) indoor system (a fully indoor barn), (2) choice system (cows have agency to choose to be indoors or outdoors), (3) gene edition + pasture (cows are genetically modified to become more resilient to heat stress), and (4) pasture (outdoor system that is currently used in Australia, but the farmer plants more trees). Participants were then asked to respond to questions on a 7-point Likert scale. Questions were about cow welfare (3 questions), confidence in dairy industry (4 questions), and trust in farmers (9 questions), with each section followed by an open-ended question for participants to explain their answers. Participants perceived cow welfare to be the lowest in the indoor system (2.80 ± 0.10), followed by gene edition + pasture (4.48 ± 0.11), with choice and pasture systems being the highest but not different from each other (5.41 ± 0.11 and 5.32 ± 0.11, respectively). Confidence in the dairy industry was lower among participants in the indoor (4.78 ± 0.08) compared with participants assigned to the choice (5.28 ± 0.08) or pasture (5.25 ± 0.08) systems. Confidence was also lower among participants in the gene edition (4.95 ± 0.08) compared with the choice system. Trust in farmers was similar across all treatments. Our results provide the first evidence that the Australian public may be reluctant to accept heat stress mitigation strategies that either do not allow cows to have access to pasture or those that include gene-editing technologies.
**Key words:** heat stress, pasture, gene editing, public perceptions, climate change

## INTRODUCTION

Elevated temperatures have long been known to increase the risk of dairy cows experiencing heat stress [e.g., temperature humidity index (**THI**) ≥72, corresponding to 25°C and 50% relative humidity; Ravagnolo et al., 2000; Polsky and von Keyserlingk, 2017]. The increase in temperature variability around the world, arguably a consequence of climate change, can dramatically affect thermal stress of dairy cows, posing challenges for both production and farm animal welfare (see reviews by Gauly et al., 2013; Lacetera, 2018). The detrimental consequences of heat stress to dairy cattle include negative effects on reproduction (De Rensis and Scaramuzzi, 2003), milk production (Ouellet et al., 2019), rumination (Moretti et al., 2017), and cow behavior (Tsai et al., 2020; Herbut et al., 2021).

It is projected that Australia will experience annually an additional 31 to 42 heat stress days (defined as THI ≥75) by 2050 (Nidumolu et al., 2014), a fact that is often discussed by industry stakeholders in combination with proposed targets to reduce greenhouse gases (Cullen and Eckard, 2011) and challenges associated with herbage growth in response to climate change (Tubiello et al., 2007). These challenges are often cited as reasons for increasing the adoption of indoor systems (Williams et al., 2020) in some regions of the predominantly grazing-based dairy industry. Although some argue that there are numerous environmental benefits to moving toward zero-grazing systems (Capper et al., 2009), there is considerable evidence from other countries that failing to provide cows access to

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pasture places the industry at odds with public values (Canada and the United States, Schuppli et al., 2014; United States, Cardoso et al., 2018; Brazil, Hötzel et al., 2017; United Kingdom, Jackson et al., 2020). To our knowledge, this has not been explored from the perspective of the Australian public.

To date, the majority of solutions targeting heat stress mitigation on dairy farms have focused on technical solutions for indoor housed cows, such as installing fans in the barns (e.g., Almuhanna et al., 2021) and using soakers to water down cows (e.g., Chen et al., 2016). Grazing-based dairy production systems are not exempt from the negative effects of heat stress (Osei-Amponsah et al., 2020). Within Australia, recommendations for managing heat stress in grazing-based systems have been mostly limited to management changes, including amending milking times to early morning and late evening, installing water sprinklers for the dairy parlor yard, and planting trees or installing shade structures (Dairy Australia, 2019). Grazing-based dairy systems will likely face increasing challenges as the number of hot days and duration of heat events are predicted to increase (Horton et al., 2016), placing expectations on the industry to identify solutions that mitigate the effects of heat stress in animals under their care (Havstad et al., 2018). Challenges associated with heat stress may be further exacerbated by farmers in some regions of Australia removing trees from their pasture to allow for the installation of large, automated irrigation systems, driven by the need for increased water-use efficiency (Finger, 2005).

Incorporating technology into agricultural systems has also gained considerable traction over the last decade (Berckmans, 2017), particularly in dairy farming (e.g., estrus detection, Roelofs and van Erp-van der Kooij, 2015). One new technology that has received some attention in animal agriculture is gene edition, a controlled change in the DNA of a living organism (Yunes et al., 2021). This technology has been cited as having the potential to revolutionize animal agriculture given that it could provide a rapid solution to many challenging issues (Proudfoot et al., 2020). One proposed gene-editing solution involves inserting the heat tolerance gene (SLICK), commonly found in heat resistant cattle (e.g., Senepol, Brahman), into the genome of breeds such as Holstein that evolved in more temperate climates (Dikmen et al., 2014; Angus, Dikmen et al., 2018); this gene causes an increase in thermoregulatory ability which reduces the risk that the cattle will suffer from heat stress (Dikmen et al., 2014). However, Werkheiser (2020) reminds us that despite many new technologies having the potential to address some of the current challenges faced by farmers, thoughtful consideration is needed given that different stakeholders may have unique perspectives.

One key stakeholder is the public, defined for the purposes of this discussion as individuals living in communities who have little to no involvement in the dairy industry and arguably little knowledge of farming practices (Ritter et al., 2021). This stakeholder is key to the discussion given that they are the primary purchasers of products arising from animal agriculture. However, in addition to their role as consumers, members of the public are citizens of the community, thereby contributing to the development of societal values (Rollin, 2011). Public concerns calling for increased care for farm animals have been well documented (Clark et al., 2016). Some evidence also indicates that the public believe that farmers have a moral responsibility to provide protection to the animals under their care, including mitigating effects of heat stress (Cardoso et al., 2018). In the latter study, qualitative responses provided by the participants indicated that a lack of protection from heat stress is seen as a failure in the farmer's duty of care toward their cattle.

From previous North American and European studies, it is becoming increasingly clear that many members of the public prefer dairy cattle systems that allow for greater freedom of movement (less time spent tethered; Robbins et al., 2019), provide cows the ability to graze (Jackson et al., 2020), and promote a good life for the animals (Cardoso et al., 2016). After touring a Canadian dairy farm, members of the public highlighted elements that they considered essential for a good life for a cow, specifically mentioning their concerns over the fact that the cows did not have pasture access, fresh air, and sunshine (Ventura et al., 2016). Public acceptance of gene edition strategies in dairy farming is generally low, even when the use of gene edition aims to address potential animal welfare issues such as heat stress or dehorning (Yunes et al., 2021).

Stakeholders working within agriculture have been slower to acknowledge the public's role as "political economic actors" (as defined by Slocum, 2004, p. 763). Most working within agriculture frequently use the term consumers when referring to the public, but others have suggested that there is merit in differentiating between consumers and citizens (Grunert, 2006). There is little doubt that the values of consumers can directly affect farm practices if individuals "choose to vote with their wallet by refusing to buy certain products that are produced in ways that they do not approve" (von Keyserlingk et al., 2013, p. 5418) but evidence indicates that the consumer is largely uninformed about animal agriculture and makes the decision on what to buy based primarily on price (Ingenbleek and Immink,

2011; Harvey and Hubbard, 2013). However, it is the dissatisfied citizen that influences the political system through their support for changes in policies and regulations. This disconnect between consumer purchasing information and public attitude surveys may explain at least in part why those working within agriculture are often surprised when in some situations the public sides with solutions that align with demand for changes in practice (or complete rejection of animal products, such as purchasing plant-based products rather than animal products; Boaitey and Minegishi, 2020) and not with current farming practices (see Ventura et al., 2016). To avoid missteps associated with adopting technologies or alternative systems that fail to resonate with societal values (Weary et al., 2016), there is merit in investigating how the public in their role as citizens will embrace solutions to existing challenges, including how to best mitigate the effects of heat stress in cattle. The aims of this study were to determine Australian public perceptions of different farm system adaptations that, if implemented, could mitigate the negative effects of heat stress in grazing dairy cattle. Specifically, we were interested in how the public evaluated 4 different proposed adaptations that could mitigate heat stress in cattle in relation to perceived cow welfare, confidence in the dairy industry, and trust in farmers. We hypothesized that solutions that retained pasture access for cows would be more acceptable to the public than solutions that did not include access to pasture due to a greater alignment of pasture-inclusive systems with public values. However, due to low public acceptance of gene edition, we hypothesized that participants would not view gene edition + pasture as an acceptable strategy to mitigate heat stress.

## METHODS

This study was approved by the University of British Columbia's Behavioral Ethics Board (H21-00047).

### Recruitment and Participants

A representative sample of participants residing in Australia were recruited during the last 2 wk of April 2021, through Pureprofile (Market Research Group, New South Wales, Australia). Participants were recruited to meet Australian census values (Australian Bureau of Statistics, 2016) for gender, age, state or territory, and place of residence (urban or rural). Once participants met the criteria to be included in the study, they were redirected to the survey (see Supplemental File S1, https://doi.org/10.5683/Sp3/EVNM1G, Hendricks et al., 2022). Each participant was paid $AUD 2.00 (US$1.50) upon completion of the survey.

### Study Design

We used a convergent parallel mixed-methods design that involved quantitative measures followed by open-ended responses (Creswell and Clark, 2011). The survey was created using the UBC-hosted Qualtrics platform (Qualtrics, 2020). After consenting to participate, each participant was given additional demographic questions (e.g., income, education). Participants were then presented with the following information about dairy production in Australia:

"Australia's climate has warmed on average by 1.44°C since 1910, leading to an increase in the frequency of extreme heat events. This means that many cows experience heat stress with an increase in hot days. Given the increase in hot days and concerns about cows experiencing heat stress, farmers are planning to change their management practices to address this."

After receiving the above information, participants were then randomly presented with one of 4 treatments (Table 1). After reading their allocated vignette, participants were presented with a series of questions on a 7-point Likert scale (with a score of 1 indicating the most negative end of the scale, 7 the most positive, and 4 being a neutral midpoint; Table 2) to investigate perceptions surrounding perceived cow welfare (i.e., cow welfare; 3 questions adapted from Cardoso et al., 2018), confidence in the dairy industry (4 questions adapted from Tomkins et al., 2010), and trust in the farmer (9 questions adapted from Frewer et al., 1996). Each series of questions was followed by an open-ended response question to allow participants to explain their responses. Included in these questions was a manipulation check to remove participants that were not paying attention to the instructions (Oppenheimer et al., 2009). Participants were also given 4 questions surrounding their strength of attitude toward the dairy industry [adapted from attitude strength and moral conviction measure questions (Skitka et al., 2005)] on a 5-point Likert scale (with a score of 1 indicating the lowest strength and 5 the highest; Table 3). Given that the concepts of trust (Frewer et al., 1996), and attitude strength and moral convictions (Skitka et al., 2005) are discussed as multidimensional and inherently difficult to predict with singular items or constructs, we specifically chose the questions in our survey to investigate general self-reported perceptions around the amount of trust in one group (farmers) and the confidence in

**Table 1.** Vignettes (text given to participants) for each experimental treatment describing a potential dairy farm management strategy adopted by a farmer in an attempt to mitigate the effects of dairy cattle heat stress that is predicted to worsen due to the effects of climate change, and the debrief statement that was provided to the participants after they completed the survey

| Treatment | Vignette | Debrief at end of survey |
|---|---|---|
| Choice | One farmer is planning to keep their cows indoor/outdoor. An indoor/outdoor dairy allows cows a choice between indoors and outdoors. When indoors, cows have a place to lie down, are provided fans, and can eat a diet of grain and hay grown and prepared by the farmer. When outdoors, cows can graze grass and have access to shade trees. | The description that you have read is hypothetical. Approximately 95% of the Australian dairy industry is pasture-based. |
| Indoor | One farmer is planning to keep their cows indoors. An indoor dairy is an enclosed facility that cows are kept in at all times of the year with no access to grass to graze. Cows have a place to lie down and are provided fans. While indoors, the cows can eat a diet of grain and hay grown and prepared by the farmer. | The description that you have read is hypothetical. Approximately 95% of the Australian dairy industry is pasture-based. |
| Gene edition + pasture | One farmer is planning to use genetic modification. Cattle can be genetically modified to make them more resistant to heat stress by adding genes from other cattle breeds. As a result, all calves are born more resistant to heat. These cows are kept outdoors, can graze grass, and have access to shade from trees. | The descriptions that you have read are hypothetical. Genetic modification of animals is not used in the Australian dairy industry. |
| Pasture | One farmer is planning to keep their cows outdoors. An outdoor dairy is an outdoor facility where cows are kept outside at all times of the year with access to grass to graze. When outdoors, cows have access to shade trees. Farmers have planted more trees to provide additional shade for the cows. | The description that you have read generally reflects current practice in the dairy industry. Approximately 95% of the Australian dairy industry is pasture-based. |

and strength of attitude toward one industry (dairy). As such, the questions were not used to disentangle potential individual factors underlying different levels of trust, confidence, or attitude strength toward different actors and issues.

Finally, participants were asked how this system would influence their purchasing intent ("What would you be willing to pay for 1 liter of milk from the described farm compared to what you spend on milk now?" The possible answer choices were: "more," "the same," "less," or "I would buy an alternative plant-based milk."). Questions about willingness to pay for animal products have been used in previous studies to help investigate public perceptions of farm animal welfare

**Table 2.** Questions and statements presented to Australian participants to assess perceptions of different proposed management changes for dairy farms to combat climate change, presented on a 7-point Likert-type scale (with a score of 1 indicating the most negative end of the scale, 7 the most positive, and 4 being a neutral midpoint)

| Question or statement |
|---|
| Cow welfare (adapted from Cardoso et al., 2018) |
| How much do you disagree or agree with the way these cows are being raised? |
| How inappropriate or appropriate do you consider the cow's living conditions to be? |
| Do you consider the way these cows are living to be unacceptable or acceptable? |
| Please provide an explanation for your responses above (open-ended) |
| Confidence in the dairy industry (adapted from Tomkins et al., 2010) |
| I have great confidence in the Australian dairy industry |
| I am satisfied with the Australian dairy industry |
| Members of the Australian dairy industry care about what people like me think |
| Most members of the Australian dairy industry lack integrity (reverse scored) |
| Please provide an explanation for your responses above (open-ended) |
| Trust in farmers (adapted from Frewer et al., 1996) |
| Information about farm animal well-being from farmers is trustworthy |
| Information about farm animal well-being from farmers is accurate |
| Information about farm animal well-being from farmers is factual |
| Farmers are likely to withhold information from the public about farm animal welfare (reverse scored) |
| Information about farm animal welfare from farmers is distorted (reverse scored) |
| Farmers are knowledgeable about farm animal welfare |
| Farmers have a good track record of providing information about farm animal welfare |
| Farmers feel a sense of responsibility to provide good information about farm animal welfare to the public |
| Information about farm animal welfare from farmers has been proven wrong in the past (reverse scored) |
| Please provide an explanation for your responses above (open-ended) |

**Table 3.** The number (and percentage) of Australian participants by treatment and compared with 2016 census data for age, place of residence, gender identity, education state or territory, and income

| Variable | Census, % | Total | Choice | Indoor | GE + Pasture[1] | Pasture | $P^2$ |
|---|---|---|---|---|---|---|---|
| Total participants | 100.00 | 781 (100.00) | 190 (24.33) | 205 (26.25) | 192 (24.58) | 194 (24.84) | |
| Age | | | | | | | 0.7428 |
| 18–24 | 11.79 | 90 (11.52) | 22 (2.82) | 27 (3.46) | 17 (2.18) | 24 (3.07) | |
| 25–34 | 18.51 | 129 (16.52) | 28 (3.59) | 30 (3.84) | 37 (4.74) | 34 (4.35) | |
| 35–44 | 17.29 | 126 (16.13) | 35 (4.48) | 37 (4.74) | 32 (4.10) | 22 (2.82) | |
| 45–54 | 17.06 | 137 (17.54) | 37 (4.74) | 35 (4.48) | 33 (4.23) | 32 (4.10) | |
| 55–64 | 15.13 | 132 (16.90) | 33 (4.23) | 33 (4.23) | 28 (3.59) | 38 (4.87) | |
| 65+ | 20.22 | 167 (21.38) | 35 (4.48) | 43 (5.51) | 45 (5.76) | 44 (5.63) | |
| Place of residence | | | | | | | 0.9524 |
| Urban | 64.80 | 495 (63.38) | 118 (15.11) | 133 (17.03) | 121 (15.49) | 123 (15.75) | |
| Rural | 35.20 | 286 (36.62) | 72 (9.22) | 72 (9.22) | 71 (9.09) | 71 (9.09) | |
| State or territory | | | | | | | 0.9900 |
| New South Wales | 31.98 | 246 (31.50) | 59 (7.55) | 67 (8.58) | 62 (7.94) | 58 (7.43) | |
| Queensland | 20.03 | 166 (21.25) | 43 (5.51) | 42 (5.38) | 35 (4.48) | 46 (5.89) | |
| South Australia | 7.04 | 52 (6.66) | 9 (1.15) | 16 (2.05) | 13 (1.66) | 14 (1.79) | |
| Tasmania | 2.14 | 16 (2.05) | 4 (0.51) | 3 (0.38) | 6 (0.77) | 3 (0.38) | |
| Victoria | 25.61 | 199 (25.48) | 48 (6.15) | 52 (6.66) | 51 (6.53) | 48 (6.15) | |
| Western Australia | 10.53 | 83 (10.63) | 21 (2.69) | 20 (2.56) | 21 (2.69) | 21 (2.69) | |
| Australian Capital Territory | 1.67 | 12 (1.54) | 3 (0.38) | 3 (0.38) | 2 (0.26) | 4 (0.51) | |
| Northern Territory | 1.00 | 7 (0.90) | 3 (0.38) | 2 (0.26) | 2 (0.26) | 0 (0.00) | |
| Gender identity[3] | | | | | | | 0.3265 |
| Female | 50.70 | 401 (51.41) | 102 (13.08) | 108 (13.85) | 88 (11.28) | 103 (13.21) | |
| Male | 49.30 | 378 (48.46) | 86 (11.03) | 97 (12.44) | 104 (13.33) | 91 (11.67) | |
| Nonbinary | | 1 (0.13) | 1 (0.13) | 0 (0.00) | 0 (0.00) | 0 (0.00) | |
| Education | | | | | | | 0.6403 |
| Did not graduate high school | | 70 (8.96) | 16 (2.05) | 14 (1.79) | 20 (2.56) | 20 (2.56) | |
| High school graduate | | 151 (19.33) | 47 (6.02) | 42 (5.38) | 36 (4.61) | 46 (5.89) | |
| Some college, no degree | | 128 (16.39) | 17 (2.18) | 35 (4.48) | 22 (2.82) | 24 (3.07) | |
| Trade qualification | | 112 (14.34) | 39 (4.99) | 39 (4.99) | 35 (4.48) | 30 (3.84) | |
| Bachelor degree | | 92 (11.78) | 51 (6.53) | 52 (6.66) | 53 (6.79) | 55 (7.04) | |
| Postgraduate degree | | 68 (8.71) | 20 (2.56) | 23 (2.94) | 26 (3.33) | 19 (2.43) | |
| Income (pre-tax) | | | | | | | 0.5281 |
| Less than $20,000 | | 42 (5.38) | 4 (0.51) | 15 (1.92) | 12 (1.54) | 11 (1.41) | |
| $20,000–$39,999 | | 151 (19.33) | 36 (4.61) | 37 (4.74) | 37 (4.74) | 41 (5.25) | |
| $40,000–$59,999 | | 128 (16.39) | 35 (4.48) | 32 (4.10) | 33 (4.23) | 28 (3.59) | |
| $60,000–$79,999 | | 112 (14.34) | 26 (3.33) | 35 (4.48) | 26 (3.33) | 25 (3.20) | |
| $80,000–$99,999 | | 92 (11.78) | 28 (3.59) | 21 (2.69) | 23 (2.94) | 20 (2.56) | |
| $100,000–$119,999 | | 68 (8.71) | 18 (2.30) | 17 (2.18) | 13 (1.66) | 20 (2.56) | |
| $120,000–$139,999 | | 46 (5.89) | 6 (0.77) | 16 (2.05) | 7 (0.90) | 17 (2.18) | |
| $140,000–$159,999 | | 45 (5.76) | 12 (1.54) | 10 (1.28) | 13 (1.66) | 10 (1.28) | |
| $160,000–$179,999 | | 18 (2.30) | 5 (0.64) | 4 (0.51) | 4 (0.51) | 5 (0.64) | |
| $180,000–$199,999 | | 39 (4.99) | 12 (1.54) | 6 (0.77) | 10 (1.28) | 11 (1.41) | |
| More than $200,000 | | 40 (5.12) | 8 (1.02) | 12 (1.54) | 14 (1.79) | 6 (0.77) | |

[1]GE = gene edition.

[2]*P*-values are from Fisher's exact test to show any contingency with treatment. $P > 0.05$ for each demographic suggests that demographic variables were independent of which treatment participants were assigned.

[3]In the general linear models, gender identity was treated as a variable consisting of 2 levels: "Female" compared with "Does not identify as female," with the 378 participants who selected "Male" and the 1 participant who selected "Nonbinary" making up the "Does not identify as female" level.

(see review by Clark et al., 2017). Participants were then thanked for their time at the conclusion of the survey and a debrief statement was provided (Table 1).

### Quantitative Analysis

Quantitative analysis was performed using SAS [version 9.4, SAS Institute Inc.; see Supplemental File S2, for the quantitative dataset (from the final sample of participants) used in analysis; see Supplemental File S3 for the SAS code file; https://doi.org/10.5683/Sp3/EVNM1G, Hendricks et al., 2022]. Questions that were negatively worded were reverse scored. The internal consistency reliability within the different series of questions presented to participants (cow welfare, confidence in the dairy industry, trust in the farmer, and attitude strength) was high (Cronbach $\alpha = 0.94$, 0.87, 0.91, 0.86, respectively; Ellis, 2016) and so each of these were collapsed into constructs. Trust in the farmer initially consisted of 10 questions, but one

question was dropped following a low corrected item-total correlation for this item (0.22). Once this item was removed, the trust in the farmer construct had a higher internal consistency (Cronbach $\alpha = 0.93$). The corrected item-total correlations for each of the other items within each construct were high (greater than 0.6 in all cases). Attitude strength was tested as a dependent variable in preliminary general linear models, but there were no effects of either treatment or treatment plus demographics. Attitude strength was thus included as a covariate in the general linear models of the other dependent variables (cow welfare, confidence in the dairy industry, trust in the farmer). General linear models were constructed for each of the dependent variables (cow welfare, confidence in the dairy industry, trust in the farmer) testing the effect of treatment, of demographics [i.e., age (continuous), gender (female vs. does not identify as female), area of residence (urban vs. rural), income (11 levels), education (5 levels), and state or territory (8 levels)], of attitude strength, and of interactions between demographics and treatment. Type III sum of squares and Tukey-Kramer adjustments for posthoc pairwise comparisons were assessed. Interaction terms with $P > 0.05$ in preliminary models were removed. Thus, only the interaction between treatment and gender was included in all final models. The interaction between treatment and age was also included only in the final model for cow welfare ($P \leq 0.05$ in preliminary models). All other variables were retained for the final models. The effects of variables with $P \leq 0.05$ are discussed for each model below. Least squares means (also known as estimated marginal means; Searle et al., 1980) and standard errors (± SE) are presented from these models below for the effect of treatment. For the calculation of these means, the coefficients of other categorical variables were set to reflect the sample population being modeled and these means were also computed using separate margins for each treatment level (to make them estimable in the models). In effect, the resulting least squares means for each treatment level are equivalent to the raw means.

A chi-squared test for independence was used to test for an association between treatment and participant's willingness to pay (i.e., more, the same, less, or to purchase a plant-based alternative instead) for milk from their treatment system.

### Qualitative Analysis

Generic qualitative inquiry was used to approach the qualitative data. Within this approach, inductive analysis (Percy et al., 2015) was used to uncover themes and patterns expressed in the participants' responses. Responses were assigned to codes through an initial round of open coding, and related codes were clustered into themes. The themes and codes were collectively organized into a codebook. Then, in an iterative process, the codebook was revised to ensure relation to the data and relevance to the research questions. The resulting codebook was checked for reliability by having 2 researchers (K.M. and J.H.) coded a randomized subsample of responses. Inconsistencies in coding were discussed and changes to the codebook were made accordingly, and a final subsample of responses was coded by both researchers using the finalized version of the codebook. One researcher (J.H.) then coded all responses with the finalized codebook.

Anonymous identifiers beginning with AU followed by a random number from 1 to 781 and the assigned treatment (Choice, indoors, gene edition + pasture, or pasture) were assigned to each participant and are used to label quotes presented in this paper (e.g., AU364; Choice or AU745; Pasture). The qualitative dataset can be viewed in Supplemental File S4 (https://doi.org/10.5683/Sp3/EVNM1G, Hendricks et al., 2022). Any explanatory information to maintain meaning of quotes or use of an ellipsis to shorten quotes were presented in square brackets (e.g., [. . .]) within the quotes. Minor spelling errors within quotes were edited for presentation unless such edits would change the meaning of quotes.

## RESULTS

After removing incomplete responses, 1,191 participants completed the survey. Respondents were removed from the sample if they failed the manipulation check (n = 200), provided invariant responses (n = 109; Curran, 2016), or did not answer the text response questions (n = 101). This resulted in a final sample of 781 participants. The number (and percentage) of participants by treatment and compared with census data (Australian Bureau of Statistics, 2016) for age, place of residence, gender identity, education state or territory, and income are presented in a contingency table (Table 3), with Fisher's exact test ($P > 0.05$ for each demographic variable) suggesting that demographic variables were independent of which treatment participants were assigned to.

### Quantitative Findings

***Perceptions of Cow Welfare.*** Treatment had an effect on perceptions of cow welfare ($F_{3,753} = 9.44$, $P < 0.0001$; see Figure 1 for participant responses by treatment). Participants perceived cow welfare to be the lowest in the indoor treatment (2.80 ± 0.10), compared with the gene edition + pasture (4.48 ± 0.11), choice

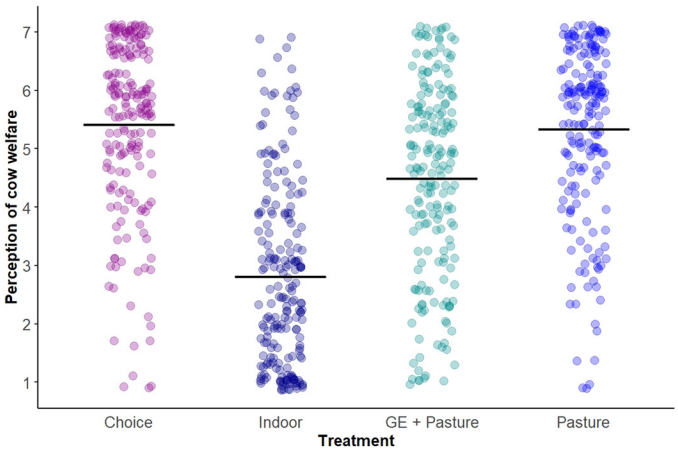


**Figure 1.** Australian participant (n = 781) responses to questions regarding perceived cow welfare when presented with 1 of 4 treatments [choice, indoor, gene edition (GE) + pasture, and pasture]. Participants responded to questions on a 7-point Likert-type scale (with a score of 1 indicating the most negative end of the scale, 7 the most positive, and 4 being a neutral midpoint). Black bars represent the means for each treatment. Purple circles represent participants in the choice treatment, dark blue circles represent participants in the indoor treatment, light green circles represent participants in the GE + pasture treatment, and lighter blue circles represent participants in the pasture treatment.

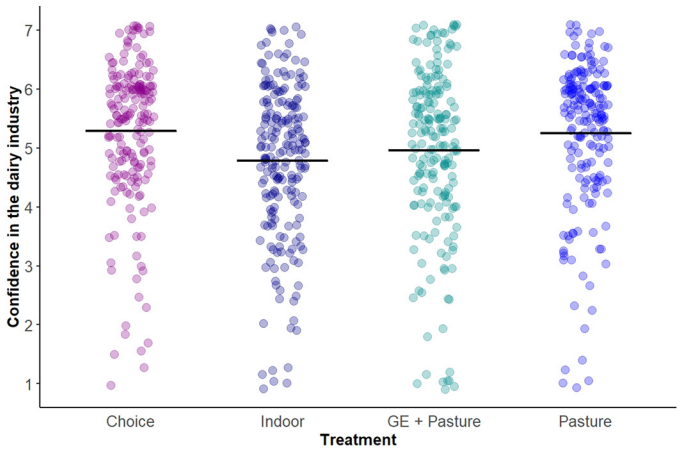


**Figure 2.** Australian participant (n = 781) responses to questions regarding perceived confidence in the dairy industry when presented with 1 of 4 treatments [choice, indoor, gene edition (GE) + pasture, and pasture]. Participants responded to questions on a 7-point Likert-type scale (with a score of 1 indicating the most negative end of the scale, 7 the most positive, and 4 being a neutral midpoint). Black bars represent the means for each treatment. Purple circles represent participants in the choice treatment, dark blue circles represent participants in the indoor treatment, light green circles represent participants in the GE + pasture treatment, and lighter blue circles represent participants in the pasture treatment.

(5.41 ± 0.11), or pasture treatments (5.32 ± 0.11). Participants also had lower perceptions of cow welfare in the gene edition + pasture treatment compared with the choice and pasture treatments. However, participants' perceptions of cow welfare were not different between the choice and pasture systems.

***Confidence in the Dairy Industry and Trust in Dairy Farmers.*** Treatment had an effect on the participants' confidence in the dairy industry ($F_{3,756}$ = 7.14, $P < 0.0001$; see Figure 2 for participant responses by treatment). Participants assigned to the indoor treatment had lower confidence in the dairy industry (4.78 ± 0.08) compared with those that received the choice (5.28 ± 0.08) and pasture (5.25 ± 0.08) treatments. There were no differences in confidence in the dairy industry between participants assigned the indoor and gene edition + pasture (4.95 ± 0.08) treatments. Confidence in the dairy industry was lower in the gene edition + pasture treatment compared with the choice treatment, but not compared with the pasture treatment. There were no differences in confidence in the dairy industry between participants assigned the choice and pasture treatments. Treatment had no effect on trust in dairy farmers between the treatments ($F_{3,756}$ = 1.88, $P = 0.131$; see Figure 3 for participant responses by treatment).

***Demographic and Attitude Strength Effects.*** Age ($F_{1,753} = 5.72$, $P = 0.0170$), gender ($F_{1,753} = 11.59$, $P = 0.0007$), place of residence ($F_{1,753} = 11.10$, $P = 0.0009$), and attitude strength ($F_{1,753} = 18.04$, $P < 0.0001$) each had an effect on perceptions of cow welfare. Participants who were younger, female (compared with those who did not identify as female), who resided

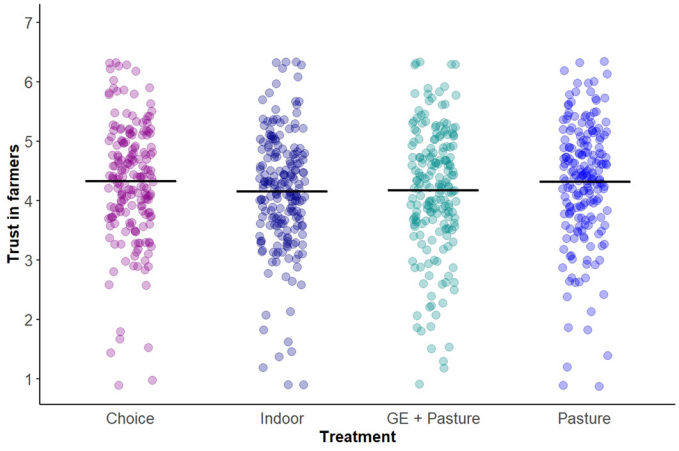


**Figure 3.** Australian participant (n = 781) responses to questions regarding perceived trust in farmers when presented with 1 of 4 treatments [choice, indoor, gene edition (GE) + pasture, and pasture]. Participants responded to questions on a 7-point Likert-type scale (with a score of 1 indicating the most negative end of the scale, 7 the most positive, and 4 being a neutral midpoint). Black bars represent the means for each treatment. Purple circles represent participants in the choice treatment, dark blue circles represent participants in the indoor treatment, light green circles represent participants in the GE + pasture treatment, and lighter blue circles represent participants in the pasture treatment.

in urban areas (compared with rural areas), or who had lower attitude strength toward the dairy industry, reported lower perceived cow welfare. Additionally, there was an interaction between treatment and age ($F_{3,753} = 4.45$, $P = 0.0041$); perceptions of cow welfare in the gene edition + pasture treatment and in the status-quo treatments increased slightly with age of participants, whereas perceptions of cow welfare appeared to stay the same or slightly decrease within the choice and indoor treatments with increasing age of participants. There was also an interaction between treatment and gender ($F_{3,753} = 2.97$, $P = 0.0310$). Female participants had lower perceptions of cow welfare in the gene edition + pasture treatment compared with in the choice and in the pasture treatments. In contrast, participants who did not identify as female did not perceive the gene edition + pasture treatment as having lower cow welfare compared with in the choice and in the pasture treatments.

Age ($F_{1,756} = 34.19$, $P < 0.0001$), place of residence ($F_{1,756} = 8.49$, $P = 0.0037$), and attitude strength ($F_{1,756} = 103.62$, $P < 0.0001$) had similar effects on perceptions of confidence in the dairy industry as on perceptions of animal welfare. Additionally, income ($F_{1,756} = 19.70$, $P < 0.0001$) and education ($F_{5,756} = 2.37$, $P = 0.0377$) affected how participants perceived confidence in the industry. Participants who were younger, who resided in urban areas (compared with rural areas), who had lower attitude strength, who had lower income, or who reported receiving a postgraduate education (in comparison to those who reported high school for education level) reported less confidence in the industry. There was an interaction between treatment and gender ($F_{3,756} = 3.16$, $P < 0.0242$) whereby participants who identified as female had lower confidence in the dairy industry when provided the gene edition + pasture treatment compared with those that were given the choice and the pasture treatments. This effect was not observed in participants who did not identify as female. An effect of gender difference within a treatment in confidence in the dairy industry was only present within the gene edition + pasture treatment.

Age ($F_{1,756} = 32.40$, $P < 0.0001$), place of residence ($F_{1,756} = 17.86$, $P < 0.0001$), attitude strength ($F_{1,756} = 120.78$, $P < 0.0001$), income ($F_{1,756} = 14.26$, $P = 0.0002$), and education ($F_{5,756} = 2.76$, $P = 0.0176$) each had an effect on trust in farmers. Participants who were younger, who resided in urban areas (compared with rural), who scored lower attitude strength toward the dairy industry, who had lower income, or who reported receiving a postgraduate education (in comparison to those who either reported high school, a trade qualification, or a bachelor's degree for education level) reported less trust in farmers. Although neither treatment nor gender affected perceptions of trust in farmers on their own, there was again an interaction between treatment and gender ($F_{3,756} = 4.36$, $P = 0.0047$), with female participants reporting lower perceptions of trust in farmers in the gene edition + pasture treatment compared with the choice and the pasture treatments; an effect not observed in participants who did not identify as female. Female participants given the gene edition + pasture treatment had lower perceptions of trust in farmers compared with participants who did not identify as female assigned to the same treatment.

***Reported Willingness to Pay for Milk.*** There was an association between participants' reported willingness to pay for milk (i.e., more, the same, less, or to purchase a plant-based alternative milk instead) and treatment [i.e., the system from which the milk they were asked about was coming from; $\chi^2$ (9, n = 781) = 47.63, $P < 0.0001$; Figure 4]. For example, there were more participants from the indoor treatment (than would be expected if reported purchasing intention was independent of the treatment participants were asked about buying milk from) who reported they would be willing to pay less for milk. This was also the case for the number of participants from both the indoor and the gene edition + pasture treatments reporting they would purchase a plant-based alternative rather than pay a different amount for milk in comparison to what they currently pay for milk. In contrast, there were more participants from both the choice and the pasture

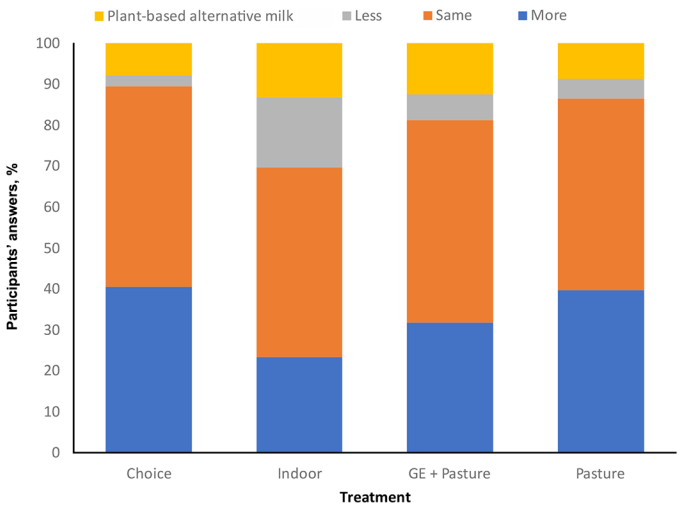


**Figure 4.** Australian participant (n = 781) responses to a question regarding willingness to pay (more, the same, less, or to purchase a plant-based alternative milk instead) for the treatment presented [choice, indoor, gene edition (GE) + pasture, and pasture], compared with what they view to be the current milk price. The relative height of each colored section of the bars represents the percentage of participants in each treatment group willing to pay more, the same, less, or for a plant-based alternative milk compared with their current milk price.

treatments than would be expected who reported they would be willing to pay more for milk in comparison to what they currently pay for milk.

***Qualitative Findings.*** Participants took a highly value-oriented approach to their views of the dairy farm systems and expressed specific concerns regarding cow management in the open-ended responses. Additionally, participants displayed a wide range of nuanced attitudes toward dairy industry stakeholders. Four overarching themes emerged from the participants' responses: effect of management change on animals, ethical considerations, stakeholder characteristics, and advocating for farmers. These themes were discussed by participants from all 4 treatments. In general, the first 2 themes emerged from the open-ended responses pertaining to cow welfare, whereas the latter 2 themes appeared in the responses pertaining to confidence in the industry and trust in farmers.

***Effect of Management Change on Animals.*** When asked to expand on their perception of cow welfare within the farm system, participants voiced concerns about specific components of the cows' living environment, including access to food, shade, and water, exposure to extreme weather conditions, freedom of movement within the management system, the ability of the cattle to choose their living environment and have access to the outdoors, and the naturalness of the management system. In many cases, participants' responses included several of these concerns.

Participants often discussed the provision of food, shade, and water as part of their conditional acceptance of a pasture housing system, stating that "[. . .] As long as they have access to shade, food, and water, I don't see the issue with them being outside" (AU356; Pasture). Participants were also concerned about cows' exposure to extreme weather conditions in an outdoor housing system: "They should not be forced to stay out in the heat. They should have the option to come inside in the shade out of the heat, or out of the cold in winter" (AU776; Pasture). In contrast, participants who received the choice system felt that this housing type protected cows from extreme weather conditions: "Australia has a harsh climate. This system would allow the cows to escape the extremes of the weather" (AU482; Choice).

Participants who received the indoor treatment voiced concern about cows' ability to move freely or exercise within this system: "[. . .] I am not sure that exercise would be able to be provided successfully whilst indoors [. . .]" (AU682; Indoor). The inability of cows to move freely in the indoor system was argued by some participants to be cruel: "It's cruel as cows need to have fresh air and need to run around" (AU693; Indoor).

Participants placed emphasis on the ability of cows to have access to an outdoor environment. Those who received the indoor treatment often felt that the lack of pasture access for cows violated a certain standard of care: "Cows are not meant to live where they never see daylight or breathe fresh air. Battery cows is a backward, unacceptable, step" (AU519; Indoor). Although some participants acknowledged the benefits of providing cows with indoor housing, their acceptance of this management system was obstructed by their belief that cows should be granted access to pasture: "While it would be nice to be in shelter and away from the cold [or] heat they still need natural light and air and grass" (AU608; Indoor) and "I feel sorry for cows being out in the elements on hot days, however I feel like keeping cows enclosed is more cruel, and they wouldn't be eating the grass and roaming the paddocks" (AU536; Indoor). Participants in the choice group also placed value on the ability of this management system to allow cows to choose between indoor and outdoor environments: "[. . .] The cows have the choice of going in a shed where there are nice cool fans and provided with grain and hay to eat or they can graze grass outdoors with access to shady trees. Whatever the cow is more comfortable with, it is their choice which is great" (AU696; Choice). Similarly, another participant commented, "[. . .] it's appropriate to let the animals freely choose which space they want to be in (either outside or inside) [. . .], rather than forcing them to spend certain periods in one space or the other" (AU715; Choice).

Participants also made connections between the farm system and a cow's natural living environment. Participants in the pasture treatment felt that this system aligned with a cow's natural environment: "Keeping cows outdoors seems to be close to the cows' natural environment [. . .]" (AU585; Pasture). In contrast, the indoor housing system was perceived by participants as being unnatural: "It is not natural for cows to not be able to move around as freely as they wish [and] to graze what grasses they wish to" (AU672; Indoor), and this often resulted in negative perceptions of the housing system: "No access to a natural environment is cruel" (AU697; Indoor).

***Ethical Considerations.*** Participants often weighed in on their moral considerations surrounding the management of farm animals. In particular, participants who received the gene edition + pasture treatment discussed the ethics of this technology. Some participants supported gene edition due to its ability to improve animal lives: "If raising cows that have been genetically modified helps them live a better life, I am for it" (AU32; Gene edition + pasture). Others strongly opposed this practice: "I do not feel we should seek to

genetically modify animals to meet our needs. They are not material products, and this could strategically damage the planet" (AU498; Gene edition + pasture) and "I believe genetically modifying any animal is inhumane and non-natural" (AU119; Gene edition + pasture). Finally, some participants believed that other steps could be taken in place of genetic modification to improve the lives of cattle: "I don't agree that they should be genetically modified to cope with heat stress, they need to be kept in better conditions" (AU198; Gene edition + pasture) and "Probably other steps available before modifying the cow's genome. Not [opposed] to the idea but think other ways to manage heat should be addressed first" (AU492; Gene edition + pasture).

***Stakeholder Characteristics.*** In the responses pertaining to confidence in the dairy industry and trust in dairy farmers, participants discussed the characteristics of these stakeholders, including honesty and trust, as well as the belief that farmers are motivated by profit or care deeply about their animals. Interestingly, profit motive and care for animals were discussed as both competing motivations and interrelated concepts. On occasion, participants compared the characteristics of farmers to other industry stakeholders.

Participants frequently discussed their perception of farmers' or the dairy industry's level of honesty and transparency toward the public. Some participants believed dairy farmers to be honest and transparent: "I think most farmers are honest and provide accurate information" (AU174; Indoor), and "I do not think that dairy farmers would withhold or falsify information about their cattle" (AU208; Gene edition + pasture). Participants with these beliefs, however, felt that there were serious consequences of providing dishonest information in the dairy industry, and this prevented farmers from providing falsehoods to the public: "I don't think farmers would withhold information about their practices because if unethical behavior comes to light, it would damage the entire industry and jeopardize their livelihood" (AU156; Gene edition + pasture). However, some participants believed farmers to be dishonest and withholding information from the public: "I think certain things may be swept under the rug and kept from the public" (AU698; Pasture) and "I am in doubt as to whether we are told everything that goes on in the dairy industry" (AU428; Indoor). These participants often referred to farmers specifically withholding information about animal care: "I think there is an element of misinformation where the public is told the animals are treated humanely but they probably are not treated as well as we are being told" (AU340; Gene edition + pasture).

Participants also discussed their level of trust in dairy farmers. Although some participants expressed trust in farmers, "I trust our farmers to do the right thing by the land and the animals" (AU132; Gene edition + pasture) and "I think overall farmers are a trusted source of information" (AU599; Indoor), others expressed a contrasting distrust in farmers, with particular regard to their treatment of animals: "I don't trust them because there are farmers who mistreat cattle and other livestock [. . .]" (AU777; Indoor).

Some participants compared dairy farmers' honesty or accuracy of information to that of animal activists, expressing greater trust in information provided by farmers than information provided by activists: "I have seen firsthand the information as correct whereas I have also seen firsthand the information from animal activists as totally incorrect" (AU137; Choice) and "I would say information is generally accurate. In my opinion [it is] much more likely to be inaccurate [or] distorted coming from certain external organizations [or] groups (that believe they are animal welfare experts generally despite their only qualification being a dietary choice)" (AU363; Indoor).

Some participants believed that dairy farmers are motivated by profit at the expense of animal welfare: "Farmers don't care about the welfare of their animals. They just want to farm them and get the return on investment. Kill the cows to get the meat to the public. Milk the cows to provide the milk. As long as it gets done, they don't care" (AU773; Pasture) and ". . .[the] dairy industry is about profits at the cost of sustainability and happy animals" (AU520; Indoor). Other participants expressed strong opinions that farmers care deeply for their animals: "Dairy farmers treat their cattle like children. They see them as more than just a source of income. [. . .] I don't believe you would be a dairy farmer with how tough things are if you didn't love your animals" (AU87; Indoor) and "Farmers care about their animals more than they care for themselves" (AU294; Pasture). Some participants believed that this sense of care came from farmers' reliance on their livestock as a source of income: "Let's face it, it is in their interests to look after the animals. A dead or unhealthy animal doesn't make money" (AU192; Choice).

Although participants varied in their perceptions of farmer attitudes, some highlighted a belief that farmers themselves vary as individuals: "I think that while there is a good portion that care about the animal and their well-being and getting across the true facts and also trying to change the industry, there is a huge shady party that don't care" (AU377; Pasture) and "I think it's hard to paint all people with the same brush. I am sure some of them are good caring people with integrity but I imagine there are also those just out to make a profit that only think of themselves" (AU645; Pasture).

***Advocating for Farmers.*** Many participants demonstrated advocacy or support for farmers in their responses, recognizing that farming is a challenging career: "Our farmers are pushed to the limits every day, they deserve a medal" (AU283; Pasture), with some participants expressing specific concern toward a lack of income in farming: "The dairy industry is hard work and these farmers spend their whole lives working to take care of their herd with little or no recognition and hardly any pay" (AU385; Choice). Some participants were dissatisfied with the treatment dairy farmers receive from other stakeholders, such as large corporations ("Farmers need to be stopped being ripped off by big corporations that cut them down in price" AU483; Indoor), supermarkets ("The way Aussie dairy farmers have been treated by the large supermarkets in recent years [...] has been nothing short of criminal [...]" AU20; Indoor), and activists ("Farmers get a lot of stick from animal welfare advocates and have to prove themselves constantly" AU47; Choice). The belief that farmers are treated unfairly within their industry, as well as the perception of farming as a difficult profession, led some participants to express support for farmers while simultaneously rejecting the rest of the industry. In the words of one participant: "I think the dairy farmers do a fabulous job on their farms having to compete with the generic milk on the markets from the supermarkets. I have ticked disagree for my satisfaction of the dairy industry because I think more needs to be done to support the farmers. Many of the dairy farmers have left their farms because they can't make a living anymore from the industry. It would be sad to see others leave under the same reasoning. I am strongly satisfied with the farmers of dairy farms. I am unsatisfied with the treatment the farmers get" (AU100; Pasture).

## DISCUSSION

For farming systems to be widely accepted by all stakeholders, including the public, as achieving acceptable animal welfare standards, they should (or arguably must) align with the major value propositions about what constitutes a good life for animals, being basic health and functioning, affective states, and natural living (Fraser, 2008). As predicted, participants in our study demonstrated more positive perceptions toward both the choice and pasture systems than the indoor and gene edition + pasture systems.

The findings that younger, urban-residing participants, and those who identified as female had lower perceptions of cow welfare, are consistent with findings from other studies completed in the Northern Hemisphere (Mckendree et al., 2014, United States; Kupsala et al., 2015, Finland). Gender identity has been strongly linked to attitudes toward animals, with women across cultures more concerned about the welfare of animals than their male counterparts (Randler et al., 2021). The demonstration of lower confidence in the dairy industry and trust in farmers among urban-residing participants in this study are similar to the findings of Kupsala et al., (2015), where trust in animal production was lower in women and urban residents in Finland.

We observed an interaction between gender identity and treatment on each of the dependent measurements (perception of cow welfare, of confidence in the industry, and of trust in the farmer), characterized by relatively lower attitudes from female identifying participants toward the gene edition + pasture treatment. This suggests that women may have more negative perceptions specifically surrounding gene edition, which is similar to previous studies finding women are less accepting of products involving genetic modification or genetic technology, such as genetically modified food (Hudson et al., 2015) and the use of genetic technology in animal and plant production practices (Siegrist, 2000).

Through the attitude strength construct, our results show that participants that considered the dairy industry to be important to their lives were more likely to rate cow welfare, confidence in the industry, and trust in farmers higher. This is perhaps unsurprising as these participants may have been more familiar with dairy production practices, which has been shown to result in expression of less concern surrounding animal care (Clark et al., 2016).

In terms of willingness to pay for milk arising from the system described in their vignette, our results suggest that participants' purchasing intention was associated with the treatment they had been assigned. Other studies have reported how consumers are willing to pay for dairy products from practices involving good animal welfare (e.g., Napolitano et al., 2008; De Graaf et al., 2016). Ellis et al. (2009) even reported that 93% of participants in their UK-based study would pay more for good dairy welfare. These results have implications for the importance of considering consumer concerns, including surrounding perceptions of animal welfare, for the dairy industry when thinking about best management practices. However, we caution the reader when interpreting the findings from the willingness to pay question in this study, as the link between questions around willingness to pay and actual purchasing behavior is not direct, thus limiting our ability to draw strong conclusions (e.g., Liebe et al., 2011). There are also many other considerations and complex thought and emotional processes that underly people's actual purchasing behaviors in addition to concerns around

a particular issue, such as management system (i.e., treatment in this study) or animal welfare (see review by Perry and Grace, 2015).

In this study, participants' perceptions of cow welfare were influenced by the heat stress mitigation strategy presented to them in the survey. The fact that perceptions of cow welfare were higher for the gene edition + pasture treatment compared with the indoor treatment was interesting and unexpected. However, there are several studies reporting greater public acceptance of gene edition technologies when designed to improve cattle welfare compared with those whose purpose was to increase production (Ritter et al., 2019; Yunes et al., 2021). Given that the gene edition + pasture scenario used in the current study would decrease the effects of heat stress, thus improving cow welfare, the participants in this treatment may have been more likely to view the dairy industry as doing a good thing . This again speaks to participants' values surrounding different dairy farm systems in Australia. It should be noted that in 2019 the Australian government announced that it would "not regulate the use of gene-editing techniques in plants, animals and human cell lines that do not introduce new genetic material" (Mallapaty, 2019), however, Food Standards Australia New Zealand would require the approval of food derived from gene-editing techniques (Food Standards Australia New Zealand, 2019), and there are not currently any known gene edited animals in commercial production within Australia.

Naturalness was an important factor in the public's assessments, considering that participants in this study perceived cow welfare as lowest in the indoor system, and often criticized this system for the fact that it restricts cows' freedom of movement and natural behaviors. These results are supported by other studies that have found that in general, members of the public do not support systems that take away a cow's freedom of choice or freedom of movement. For example, the majority of participants in a UK survey viewed keeping cows indoors permanently as unacceptable (Ellis et al., 2009). Naturalness has been reported as desirable to members of the US public in dairy farming (Cardoso et al., 2016), and loss of naturalness has been voiced as a concern by the North American public in contentious practices such as cow-calf separation (Ventura et al., 2013). The public have expressed a strong desire for cattle to have access to pasture for either grazing or space allowance (Cardoso et al., 2016). Failure to provide access to pasture may have therefore contributed to participants' rejection of the indoor system in this study given that many participants valued access to pasture as an integral factor to a cow having a good life (see Cardoso et al., 2016 for further discussion). Similar concerns regarding the perception that the proposed farm system violated a certain 'standard of care' were also raised by some that received the pasture system; in this case the farm system was criticized for failing to protect cows from extreme heat events. This perceived failure of farmers to mitigate heat stress in outdoor systems was also shown by Cardoso et al., (2018), where American participants were told that cows on pasture would suffer from heat stress on hot days. Not surprising was the finding that proponents of the choice system, where cows had agency as to whether they wanted to be outside on pasture or inside a barn with a cooling system, felt positively about the choice system's ability to provide cows with access to pasture while also protecting them from discomfort during extreme weather. Indeed, there is a growing body of work indicating that cows alter their preference for pasture, depending on the environmental temperature (see review by Smid et al., 2020) and that when denied access to pasture cows will work as hard to access it as they will to access fresh feed after milking (von Keyserlingk et al., 2017).

The qualitative results of this survey indicate that while the public acknowledges the importance of addressing heat stress in dairy cows, they do not see this alone as a justification for employing less desirable technical interventions such as gene edition or zero-grazing systems. In the case of gene edition, Yunes et al. (2021) reported similar arguments from Brazilian participants, who believed that changes in the management of cattle should come before, or alongside, gene edition when seeking to improve cattle production or welfare. In the eyes of the public, choice systems appear to offer the 'best of both worlds,' which may go a way toward navigating what Boogaard et al. (2011) describes as an ambivalence between the 'positive and negative faces of modernity'. This dilemma recognizes that while modern interventions may improve some aspects of cow care, if taken too far they can be seen as a threat to natural values. Similar results were reported by Cardoso et al. (2018), where survey respondents felt most positively about a dairy system that provided both heat stress mitigation and pasture access and least positive about systems that provided neither pasture access nor heat stress mitigation. These findings highlight the value that citizens place in giving animals the ability to choose between natural living components and modern technical interventions that may provide higher levels of care.

Another key finding in both the qualitative and quantitative results is variation in responses throughout the surveyed population regarding trust in and support for Australian farmers and confidence in the dairy industry. Trust in farmers as a grouping reflects organizational trust, with an accepted definition developed by Mayer et al. (1995) as, "the willingness of a party to

be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party." Thus, trust in farmers and confidence in the dairy industry in the current study likely reflect the community's willingness to trust these parties to 'do the right thing' in the face of little knowledge of, or control over, their practices.

Participants' confidence in the dairy industry was influenced by treatment. We observed a reduction in confidence in the dairy industry in the indoor and gene edition + pasture treatments, thus indicating a failure of these systems to meet the participants' expectations of what the industry should do to mitigate heat stress. Trust in farmers, however, was not different across treatments. Results of previous work have indicated that farmers are viewed as more trustworthy than other stakeholders such as supermarkets, the media, government, or politicians (Frewer et al., 2005; Henderson et al., 2011). In China, however, public trust in actors of the dairy supply chain, including dairy farmers, has been reported as moderate to low (Zhang et al., 2021). The recent consumer backlash (in support of farmers) against loss-leading on milk products by Australia's 2 major supermarkets may have contributed in part to the sentimental views toward farmers articulated by many of the participants in our study. As explored by Phillipov and Loyer (2019), the media dialog surrounding the sale of $1/L milk in Australian supermarkets sought to fortify support for dairy farmers, which typically used images illustrating pasture-based traditional small-scale farms, run by multigenerational family farmers. These images reinforced the romantic images of dairy farming (see Fraser 2008), not dissimilar to the 'ideal' dairy farm described in Cardoso et al. (2016).

The expression of support for farmers in our study may also be attributed to the exhibition of 'cultural positivity' toward farmers within the Australian community. This links back to Australia's historic economic dependence on agriculture (agrarian sentiment; Berry et al., 2016), and the virtues of self-sufficiency, commitment to community, and reliability (country mindedness; Cockfield and Botterill, 2012). The cultural predisposition toward farmers and agriculture can be seen perpetuated through popular and political romanticization of "the bush" (the Australian colloquialism for regional and forested areas), with media representation of farmers as rugged and capable has further perpetuated pastoral sentimentality (Berry et al., 2016; Botterill, 2006; Phillipov and Loyer, 2019). While agrarianism is not be uniquely Australian (Christensen, 2021), associating positive attributes to farmers may account at least in part for the lingering pre-existing trust in this group by the Australian public that took part in this survey, reflected in both the quantitative and qualitative findings of our study.

Ultimately, trust is multifactorial and is built or lost with time and the experiences of the individual (Kodish, 2017). While trust in Australian dairy farmers appears to be currently maintained by the participants, trust is fragile (Buddle and Bray, 2019) and can be quickly eroded if the vulnerability of the community (as described by Mayer et al., 1995) is breached. Robbins et al. (2016) provided evidence of how failures of transparency, such as ag-gag laws, result in reduced trust in the farming industries and a reduction in the perception that farmers are trustworthy sources of information.

Given that increased hot days, among other factors, are placing pressure on pasture systems in several Australian farming regions (Williams et al., 2020), some farmers have already begun to modify their grazing systems in response to the warming weather by incorporating covered feed pads as a place to provide additional feed to the animals and provide them with access to shade (Dairy Australia, 2019). However, these and other types of shade coverings by themselves have been argued by some to be insufficient in mitigating the effects of heat stress among dairy cows in Australia (Osei-Amponsah et al., 2020).

There is, however, an opportunity to navigate a shift to alternative systems that is informed by our results. In doing so, it may be possible to design farming systems that provide cattle with the agency to behave according to their preferences (e.g., the choice system), including elements of naturalness such as pasture access while also providing modern technical innovations such as improved cooling and easy access to feed. Systems that blend both naturalistic pasture-based systems and technological advances in cooling cows could provide for improved animal welfare standards and increased public acceptability while also allowing the farm business to benefit from a system that is better adapted to modern climatic challenges. Ultimately, ensuring these factors are included in community-facing dialogs will help ensure the ongoing sustainability of the dairy industry (see Bolton and von Keyserlingk, 2021, for further discussion on this topic).

### Implications and Future Directions

The findings of this mixed-methods inquiry into Australian public perceptions of different strategies that could be implemented by dairy farmers to mitigate heat stress in their cattle provides the first insight into a range of Australian public views on this topic. We encourage future work of this kind in other grazing-based

regions, such as New Zealand, Brazil, or Chile, to investigate views in different countries and across a wider range of socio-demographics. Research that investigates the perspectives of Indigenous Peoples is also strongly encouraged (Hudson et al., 2019). We also identify the need for more work that focuses on stakeholders working within the Australian dairy industry (e.g., farmers, veterinarians, and agriculture advisors) to gain insights into their views as this will help improve our understanding of the difficulties they face when trying to manage challenges associated with heat stress (and arguably other challenges arising from climate change). Our work also suggests that the Australian public values dairy cows having access to pasture, a finding that mirrors work done in many other countries indicating that there may be some risk to the social acceptability of dairy farming if the Australian dairy industry elects to adopt zero-grazing systems.

## CONCLUSIONS

Australian participants had more positive perceptions of systems for mitigating heat stress that involve pasture access, including a system where cows have the freedom to choose between pasture or a shaded barn. Participants were less supportive of gene edition + pasture or zero-grazing (indoor) systems as solutions to mitigate heat stress in dairy cattle. Of value to participants was the ability of the farm system to provide cows access to pasture, accommodate their freedom of movement and choice, and align with their natural living environment. A better understanding of public perceptions surrounding possible solutions to potentially contentious issues may be a key first step when identifying solutions as those that resonate with societal values will be more socially sustainable.

## ACKNOWLEDGMENTS

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