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Perceptions of farming stakeholders towards automating dairy cattle mobility and body condition scoring in farm assurance schemes

J. Schillings [a,*], R. Bennett [a], D.C. Rose [b]

[a] School of Agriculture, Policy and Development, University of Reading, Reading, United Kingdom
[b] School of Water, Energy, and the Environment, Cranfield University, Cranfield, United Kingdom

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ABSTRACT

Animal welfare standards are used within the food industry to demonstrate efforts in reaching higher welfare on farms. To verify compliance with those standards, inspectors conduct regular on-farm animal welfare assessments. Conducting these welfare assessments can, however, be time-consuming and prone to human bias. The emergence of Digital Livestock Technologies (**DLT**s) offers new ways of monitoring farm animal welfare and can alleviate some of the challenges related to animal welfare assessments by collecting data automatically and more frequently. Whilst automating welfare assessments with DLTs may be promising, little attention has been paid to farmers' perceptions of the challenges that could prevent successful implementation. This study aims to address this gap by focusing on the trial of a DLT (a 3D machinelearning camera) to automate mobility and body condition scoring on 11 dairy cattle farms. Semi-structured, in-depth interviews were conducted with farmers, technology developers and a stakeholder involved in a farm assurance scheme (N14). Findings suggest that stakeholders perceived important benefits to the use of the camera in this context, from building consumer trust by increasing transparency to improved management efficiency. There was also a potential for greater consistency in data collection and thus for enhanced fairness across the UK dairy sector, particularly on the issue of lameness prevalence. However, stakeholders also raised important concerns, such as a lack of clarity around data ownership, reliability, and use, and the possibility of some farmers being penalised (e.g., if the technology failed to work). More clarity should thus be given to farmers in relation to data governance and evidence provided in terms of technical performance and accuracy. The findings of this study highlighted the need for more inclusive approaches to ensure farmers' concerns are adequately identified and addressed. These approaches can help minimise negative consequences to farmers and animal welfare, whilst maximising the potential benefits of automating welfare-related data collection.

Implications

We explored farmers' perceptions of automating welfare-related data collection for assurance schemes using a camera performing mobility and body condition scoring. Farmers highlighted its potential to help improve transparency, efficiency, and greater consistency in data collection. This could help enhance animal welfare through improved management, build consumer trust, and promote fairness across the dairy sector. Concerns were, however, raised regarding the possible mandatory use of the camera, and a lack of clarity regarding data reliability and handling. The importance of including farmers in early discussions to maximise the potential of Digital Livestock Technologies whilst anticipating negative consequences was therefore highlighted.

Introduction

The demand for more information on how food is being produced is growing, particularly due to increased concerns about its impacts on human health and the environment, as well as on animal welfare (Bredahl et al., 2001). In the EU, this has led policymakers to consider the importance of labelling schemes that can provide consumers with more detailed information, such as those related to animal welfare standards (European Commission, 2016 and 2020). Farm assurance scheme labels can help consumers make better-informed choices and have the potential to give producers a competitive advantage and price premiums, thus encouraging them to adapt their management practices to higher welfare

* Corresponding author.
E-mail address: j.schillings@pgr.reading.ac.uk (J. Schillings).

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husbandry systems. Specific sets of standards, which usually aim to go beyond minimum legal requirements, are defined by farm assurance schemes and in some cases by food retailers. On-farm assessments are conducted on member farms to ensure that producers adhere to these standards (Main et al., 2001). To conduct these assessments, a variety of farm animal welfare assessment protocols are available, such as those emanating from the Welfare Quality® (WQ®) project.

Whilst some of these assessment protocols offer comprehensive assessments of animal welfare, there are challenges associated with their use, including the time required to conduct them manually. The WQ® protocol for dairy cattle, for example, takes between five to seven hours to complete per farm, depending on herd size (Welfare Quality®, 2009). This makes it challenging for farm assessors to conduct frequent welfare assessments on each farm. Often, farms are assessed no more than once a year, capturing welfare levels at points in time as opposed to reflecting welfare status over the long term. In addition, there are concerns regarding the validity, reliability, and feasibility of the measures, and their sometimes-subjective nature which can impact consistency between assessors (Czycholl et al., 2016; Knierim & Winckler, 2009).

Opportunities to reduce the time taken to conduct welfare assessments have been explored (de Vries et al., 2016; Heath et al., 2014; Tuyttens et al., 2021). Whilst these shorter protocols may be considered more practical, they also have limitations such as being less comprehensive, requiring further validation, or omitting aspects of positive animal welfare. Other solutions are currently being explored, including the use of Digital Livestock Technologies (**DLT**s), which range from simple smartphone applications to more sophisticated Precision Livestock Farming (**PLF**) technologies to collect animal health and welfare-related data. A wide range of DLTs exists for various livestock species, such as sensors or boluses that can be used to monitor feed and water intake, activity or location, cameras that can detect lameness and body condition, or microphones to help monitor respiratory diseases (Schillings et al., 2021). By offering continuous, real-time, and automatic data collection, DLTs could replace the need for often laborious, costly, and time-consuming manual welfare assessments (Blokhuis et al., 2010; van Erp-van der Kooij & Rutter, 2020). They could also help reduce the subjectivity associated with manual assessments and help enhance consumer trust in labelling systems by allowing the provision of detailed information on animal welfare parameters (Fuentes et al., 2022; Ingenbleek & Krampe, 2022; Stygar et al., 2022).

Despite their potential, a recent study showed that out of 19 identified standards for certification in the EU, only one quality scheme enabled the direct use of DLTs (in this case, sensors) to provide information on animal welfare (Stygar et al., 2022). This may be explained by the fact that, despite the optimism in some policy and industry circles about digitalisation on farms (e.g., through the media or policy - Barrett and Rose, 2022), there are several important challenges that relate to technology implementation. Possible drawbacks of digital agriculture were highlighted by Rose et al. (2022) and include issues relating to data ownership, cybersecurity, data interoperability, power imbalances, food system intensification, and consumer backlash. There is a lack of transparency around data ownership and privacy due to the absence of legal and regulatory framework specifically aimed at agricultural data. This makes it unclear who benefits from the data collected, who owns it, and what is being done with it (Wiseman et al., 2019). In addition, many of these technologies are not appropriately validated (Gómez et al., 2021; Larsen et al., 2021; Stygar et al., 2021). For example, Stygar et al. (2021) found that only 14% of commercially available sensor-based DLTs for dairy cattle had external validation trials available, whilst Larsen et al. (2021) found that only 23% of information technologies developed to monitor the welfare of pigs had been properly validated. In addition to this lack of validation, concerns have also been raised about the vulnerability and potential misuse of the data, as well as the overall legitimacy of the technologies (Krampe et al., 2021; Neethirajan, 2020).

These challenges may represent important barriers to farmers' acceptance of the use of DLTs in the context of farm assurance schemes, as they can influence the trust that farmers have in these technologies and a reluctance of farmers to engage with DLTs and to share their farm data (Wiseman et al., 2019). Limited trust can hinder digitalisation and innovation processes, which in turn can affect trust relations among value chain actors and create uncertainty (Rijswijk et al., 2023). Failure to adequately identify and address these challenges in the specific context of farm assurance schemes could thus hinder their implementation and potential opportunities for improved farm animal welfare and consumer trust.

Despite the burgeoning literature on the potential impacts of using DLTs to enhance animal welfare (Schillings et al., 2021; van Erp-van der Kooij and Rutter, 2020), to our knowledge, there are no studies which explore multi-stakeholder perceptions of using DLTs to automate animal welfare assessments for farm assurance. Furthermore, in a review of the digital transformation in livestock farming with a focus on artificial intelligence, Fuentes et al. (2022) argue that there has been limited research on deployment in real-world scenarios. This study seeks to fill the gap by exploring stakeholders' perceptions of the potential benefits and challenges of using DLTs in the context of farm assurance schemes. It focuses on the trial of a machine-learning 3D camera for body condition and mobility scoring on dairy cattle farms. The use of DLTs for farm assurance involves stakeholders across the supply chain from farm to fork, including farmers, inspectors, and retailers, each of whom may perceive a different set of advantages and disadvantages that could influence adoption decisions. Ultimately, we identify a series of reasons for optimism or concern regarding the use of the camera for automated welfare-related data collection and reflect on how to learn lessons from discussions of similar issues around the pitfalls of agricultural digitalisation in the wider literature.

Material and methods

This research uses a case study approach to obtain rich, in-depth, and important insights into stakeholders' perceptions of the use of DLTs in the context of farm assurance schemes. Such an approach helps increase our understanding of the research question and to get a holistic view of a potentially complex issue (Yin, 2011).

Case study description

Mobility and Body Condition Scoring (**BCS**) are measures that are often required from farm assurance schemes since they can have important impacts on dairy cattle productivity and welfare (Whay & Shearer, 2017). Automating these measures can be particularly advantageous for these schemes since the data are usually collected manually, which can be time-consuming and prone to human errors (Silva et al., 2021). The DLT used in this case study was a machine-learning 3D camera that automatically collected mobility data (lameness) and BCS in dairy cattle. The cows were scored each time they passed beneath the camera, which was usually placed above a race e.g., at the exit of the milking parlour. Real-time data were provided to farmers, who could access these on an online platform. The camera was tested on 11 pilot farms in the UK (10 in England, and one in Scotland). Nine of the farms adhered to a

farm assurance scheme and were trialling the camera to test the automated collection of BCS and mobility data to replace the current scheme's requirement for quarterly, manual, and independent scoring. Two other farms were recruited by the technology company to test the technology. All pilot farms volunteered to have the camera installed and did not have to pay for its implementation during the trial. No stakeholders involved were incentivised to take part in the interviews. One-to-one, informal training was provided by technology developers following the installation of the camera.

Semi-structured interviews

In-depth, semi-structured interviews were conducted by the first author using topic guides (see Supplementary Material S1 for an example) to obtain a rich account of participants' experiences whilst ensuring that the conversations were steered in a way that would address the research questions. This study was part of a wider project, thus only the data that were relevant to this study were discussed. Farmers' contact details were provided by the technology developers. Initially, it was planned to conduct a 'before-and-after' type study to explore farmers' expectations and experience with the technology, using two rounds of interviews. However, difficulties linked to the COVID-19 pandemic and technical challenges encountered by the technology developers meant that at the time of the second round of interviews, only two out of the 11 farmers were able to make use of the camera. This means that the results of this study mostly related to farmers' perceptions of the issues explored, as opposed to being based on their actual experiences of using the camera (except where specified for those farmers having used the technology). Stakeholder perceptions of technology use are important to understand, however, since initial decisions to adopt are largely made by farming stakeholders on the premise of perception, rather than from direct experience of using technologies (Rose et al., 2022). Exploring these perceptions, even if some may arise from a position of lack of knowledge or experience about how the technology works in practice, is important to understand implementation challenges. The first round was conducted with the 11 farmers (farm owners/managers or partners). Discussions revolved around farmer general attitudes towards the use of DLTs, adoption factors and general challenges. The interviews were conducted between August 2020 and May 2021 for 46 minutes duration on average, using the phone or video conference software (e.g., Microsoft Teams) due to COVID-19 pandemic restrictions. The second round of interviews was conducted using the same platforms, between March 2022 and April 2022. Interviews were held for 53 minutes duration on average. The second round was conducted with nine of the 11 farmers, due to one farmer having sold their cows whilst the project was ongoing, whilst another was not able to install the technology due to a lack of system compatibility. Additionally, two technology developers and a stakeholder working for the farm assurance scheme organisation were interviewed. Whilst a deeper focus on attitudes towards the use of the camera in the context of assurance schemes mainly occurred during the second round of interviews, results from the first round of interviews helped gain a better understanding of the context and stakeholders' expectations.

Qualitative data analysis

All interviews were recorded with a smartphone application or using software recording (e.g., Microsoft Teams). The interviews were transcribed verbatim by the first author, to allow for better familiarisation with the data (Braun & Clarke, 2006). The data were analysed thematically using an inductive approach, with the help of a qualitative data analysis software (NVivo 12) for coding. Data analysis was guided by methods from Braun and Clarke (2006) and Ritchie et al. (2014). Based on the data, a thematic framework was developed with a series of themes and sub-themes covering the main topics discussed during the interviews. The data were coded into these themes, which led to new themes being created throughout the process. Then, the data were sorted e.g., each theme was reviewed, which would sometimes lead to the deletion or merging of themes. Finally, data summaries were produced for each theme to help uncover key elements and underlying dimensions that guided the interpretation of the data.

Results

Based on the discussions with farmers and other stakeholders, several important benefits of using the camera system to automate mobility and body condition scoring for a farm assurance scheme were identified. Stakeholders also reported concerns about the potential implications and possible negative consequences of using the camera in this context. Fig. 1 provides an overview of the findings which are presented below.

Fig. 1.

Perceived benefits of automated data collection

Among the benefits of automating welfare-related data collection for farm assurance schemes was the potential for improved animal welfare management through more efficient livestock monitoring. Benefits also included enhanced data consistency, which in turn could have positive impacts on consumer trust and promote fairness across the UK dairy sector.

Improved efficiency and management

The ability to monitor lameness and BCS in real time was considered a useful way to improve the assurance scheme's efficiency in terms of animal welfare outcomes. The camera could allow more frequent and precise scoring as opposed to the quarterly snapshots currently provided by independent mobility scorers. According to the assurance scheme worker (AS), this would help farmers be more proactive and allow them to obtain better results through the early detection of health and welfare compromises. As they said:

> 'The argument should be that farmers who are collecting more data in much more detail, more frequently (...) should be able to better, more practically, pick up on any potential mobility issues and then stop severe lameness entering the herd. Whereas, potentially, farmers who are only doing it quarterly won't be able to be as proactive. They might have missed some things and then it's too late, so it should be seen more as a management tool for farmers.' (AS)

One farmer supported this argument by indicating how using the camera could help them manage lameness more efficiently by focusing more, for example, on slightly lame cows. They said:

> 'On the other side, it could be a big step change for our actual individual cow treatment. Currently, we spend a lot of time trying to fix score 2 cows and make them go back to being a 1, but maybe we can intervene at that 0 or 1 threshold. I suspect it's a lot easier to get a cow from being a 1 to a 0 than a 2 to a 1.' (Farmer 6)

Similarly, another farmer who was able to make use of the system at the time of the interview mentioned:

> 'I'll probably log in twice a week and just keep an eye on it. I think as a management tool, it's been very good actually.

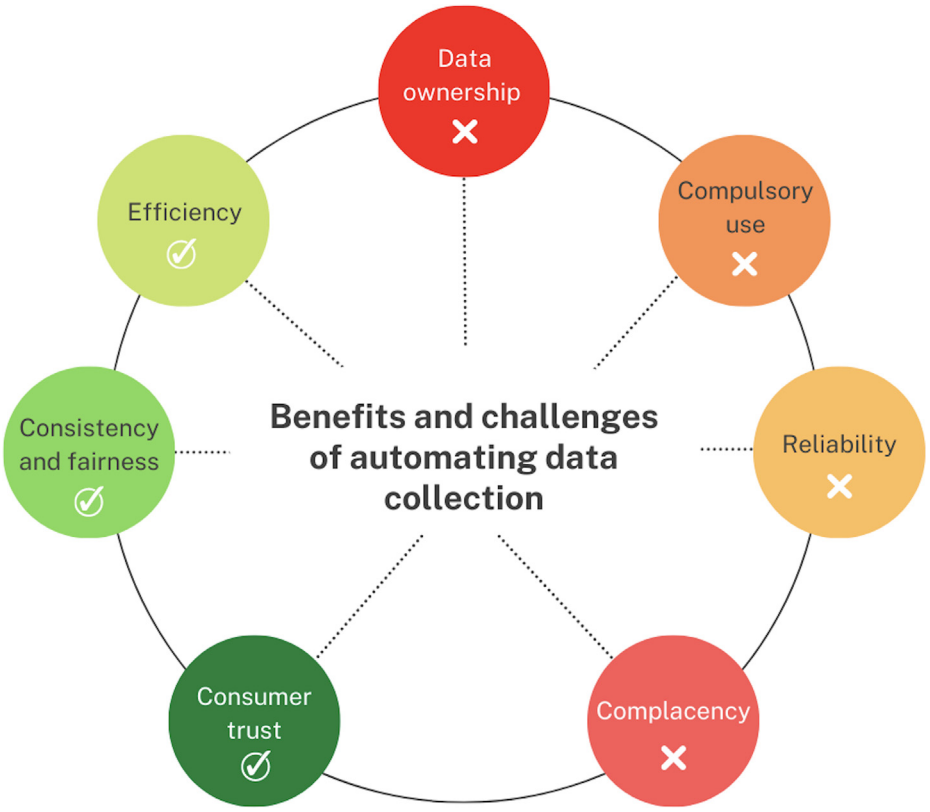

Fig. 1. Perceived benefits and challenges of automating dairy cattle welfare-related data collection (themes from interviews).

> Because we're being pushed a lot more on lameness, with our contract anyway, to try and meet the criteria they want (...). I think it probably helps me just pick some (cows) up slightly earlier than I would have done.' (Farmer 8)

To comply with the scheme's standards, farmers from the case study had to implement quarterly mobility scoring performed by independent mobility scorers. Using the camera to automate data collection was thus seen to save the time and costs associated with hiring independent scorers. As a farmer said:

> 'In the current (scheme) standards, members have to score quarterly (...) so, the thinking is that if we can automate that and (...) spot things before they can be spotted by the human eye (...), not only will it save the farmer time, but also, they'll have a better set of results. I mean, if a cow is going lame, the sooner the animal is treated, the better the outcome. (Farmer 1)

Whilst at the time of the study, farmers had to provide the data generated by the camera themselves, one farmer also considered that allowing the scheme to have direct access to the data in the future could represent a way to save time. They said:

> 'If they can get it linked to farm assurance, then again, it saves me a job. I'm quite happy with that because you know, we like working with cows. We don't do it because we like playing on computers.' (Farmer 8)

Improved data consistency and fairness

Obtaining more consistent and accurate data was also a commonly mentioned benefit according to stakeholders, who believed that automating data collection could help reduce the subjectivity of manual, human scoring. The subjective element of mobility and body condition scoring can indeed introduce inconsistencies (e.g., results differing between scorers), even where training is standardised. As one developer said:

> 'The idea of the camera is to take away the necessity for a human to do that scoring and try to automate it and make it more consistent. Because humans have an inherent subjectivity in the way that they assess, they can then end up identifying cows incorrectly, and incorrect actions could be taken as such.' (Developer 1)

Similarly, on the benefit of the camera in relation to subjectivity, a farmer mentioned:

> 'The camera doesn't care whether she's lame or not, it just says she is or isn't. I think that's how our interest has sparked.' (Farmer 6)

The camera was generally considered more reliable by stakeholders, especially since it is unobtrusive and removes the need for humans to be present, which can cause possible disturbances (cows wanting to 'hide' that they are lame). As the other developer mentioned:

> 'The cows going under the camera are completely unaware of any humans around. So, you get a true picture. If you are scoring, you're always impacting on how the cow's score (...) It's (detecting) those cows between (scores) 1 and 2 which are able to mask their mobility a little bit more.' (Developer 2)

This benefit was supported by a farmer who was able to use the camera, who mentioned that lameness on their farm had improved since using the camera:

> 'I always find when you mobility score your cows and there are people around, sometimes they'll walk a bit faster and they can maybe cover up a slight lameness, whereas when they're just going through the camera in the shed, there's no one around. They're just moving along and maybe they're walking more

'true' to how they are. So yeah, I think it has probably improved 'cause I'm finding cows slightly sooner.' (Farmer 8)

The benefit of improved data consistency mentioned above was also closely linked to the opportunity of levelling the playing field across the dairy farming sector, particularly in relation to lameness prevalence and requirements set by milk contracts. Obtaining a more accurate reflection of lameness prevalence and being more consistent across farms was a particularly important point according to farmers. One of them mentioned the pressures put by supermarkets on dairy farmers to keep lameness figures low, which meant that these figures did not always reflect reality. They emphasised the need to have a more robust system. They said:

'We don't want to sleepwalk into what (supermarkets) created; they've all done it. All their farmer-scoring information is a work of fiction, isn't it? It's not correct. Farmers, they're not liars, but they're pushed towards not telling the truth.' (Farmer 6)

Whilst the use of the camera was not meant to become a requirement from the assurance scheme at the time of the discussions, a farmer emphasised the possible benefit of making the use of the camera compulsory, to increase fairness in data collection:

'It would be a good thing to make it a requirement because it puts everyone on a level playing field. If you're all being scored by the same machine, you can't all go oh, well, he scores harsher than my score or, you know, I think there's certainly a level of fairness it could bring.' (Farmer 8)

Similar benefits were also underlined by another farmer, who said:

'The camera has its algorithm and it's always the same, whereas people are different. So, for the milk buyer, the camera is amazing because it means all the farms will be analysed exactly the same.' (Farmer 9)

Building consumer trust

Automating data collection was seen as an opportunity for farm assurance schemes to increase transparency and be able to provide evidence of compliance with welfare standards to consumers. Having the data readily available was deemed a helpful way to help farmers and assurance schemes be transparent and protected against potential exposés. As the assurance scheme worker said:

'As a responsible business, we need to have that detail if we are ever challenged on the claims we're making, we want to be transparent and truthful in everything we do. These technologies help us to have that integrity.' (AS)

Through increased transparency, an important benefit perceived by stakeholders was to help build consumer trust in the farming system and the confidence they have in farm welfare standards. As a farmer mentioned:

'They should have more confidence, shouldn't they, in the standards that are on these farms. (...) If they're aware that these systems are in place, it's bound to improve their trust in the farming system, isn't it?' (Farmer 2)

Using technologies like the camera was also considered a way to demonstrate leadership in farm assurance schemes to help consumers make better-informed choices i.e., by offering a form of guarantee that the products they are buying come from animals that have been raised according to the schemes' set welfare standards. As one farmer added:

'We're looking to improve outcome measures because the consumer wants healthier cows and wants to be secure in the knowledge that what she or he is buying comes from cows that are well looked after.' (Farmer 1)

Farmers also saw an opportunity to be able to reassure consumers about lameness levels in dairy cows, which they believed was an aspect the public was concerned about. One of them said:

'I think that lameness is definitely a biggie at the minute for the consumers (...) So I would suggest to try and make the consumer aware of what we're doing and reassure them that we were doing as much as we can on farm (...) the camera has potentially got a huge part to play.' (Farmer 5)

More generally, one farmer mentioned the potential of DLTs to facilitate consumer engagement, using tools they could more easily relate to and understand, such as the use of neck collars to measure activity which has similarities with human fitness trackers (e.g., *Fitbits*).

Perceived challenges of automated data collection

Whilst stakeholders identified several benefits of using the camera in the context of farm assurance schemes, there was also a level of uncertainty among farmers regarding the possible implications. There were concerns about a lack of clarity on data ownership, reliability, and use, as well as about possible impacts on farmers and animal welfare.

Data ownership

At the time of the study, farmers were providing the data generated by the camera to the assurance scheme themselves, as opposed to the scheme having direct access. Whilst some farmers mentioned not having a problem if the scheme did have direct access (one of them stated they had 'nothing to hide', and another mentioned the benefit of it saving them from inputting data), others saw a potential risk. A technology developer emphasised the importance of giving farmers control over data sharing (e.g., with milk buyers). They were concerned that farmers would become suspicious of what is being done with the data and have a feeling of being watched. They said:

'There is a danger if people just see it as an assurance tool (...) because it then looks a bit like Big Brother. They know that (the assurance scheme) is sort of looking and it could be seen as counterproductive. (...) Farmers would then become suspicious that (the assurance scheme) can see what's going on or the milk buyer. Then, there's no manipulation, there's no hiding from that.' (Developer 2)

In this case study, some farmers were unsure about the schemes' future intentions regarding data access. They said:

'I don't know. I'm not sure what the plan is. I mean, from a farmer's point of view, they would prefer to provide the data to them rather than them being able to have access all the time.' (Farmer 9)

Another farmer confirmed this point and emphasised the need for the data to remain theirs. They mentioned they would feel 'very uncomfortable' if third parties had direct access to the data, especially if there were risks that the technology could be faulty. They said:

'It would be so unnerving if that was the case. If your camera was malfunctioning and suddenly it said you had 400 score 3s (...) you might have a policeman knocking on your door and it was the camera that was faulty.' (Farmer 4)

The same farmer also added the potential impacts it could have on farmers:

> 'For a dairy farmer in particular, it's really traumatic if somebody comes on farm and tells them they're not doing a good job (...) It's a very difficult thing to have to tell somebody if it's true, and it's also a very difficult thing to hear. So, any statutory recording or uploading of this information would be along those lines and would be so sensitive that it just could not be happening.' (Farmer 4)

Compulsory use

Achieving consistency and fairness through automated data collection is likely to be possible only if farms are scored the same way. This could imply making the use of DLTs such as the camera compulsory. However, requiring the use of the camera would be a particular challenge, as farmers had mixed feelings about this possibility (e.g., see previous section on 'improved consistency and fairness'). One farmer, for example, mentioned how they would not like to be 'forced' to implement DLTs and to share even more data than they are already sharing. They said:

> 'I mean, we're forced to share data with our milk buyer, you know, loads of data. (...) If it is made compulsory for everybody, well, how is that going to work? You know, in general, people are not that keen on being forced to do things. It's always better to make the decision.' (Farmer 9)

Another issue related to this potential requirement was that of cost, which is a common barrier to technology adoption. In general, DLTs represent big investments for farmers and can be hard to justify depending on the size of the farms. Making the use of the camera compulsory could thus be a disadvantage for some. As one farmer said:

> 'I think there's certainly a level of fairness it could bring. But (...) to buy that machine these days, it's a significant investment. Especially on the smaller herds, it's probably quite hard to justify at the moment because (...) if you have 1000 cows and you make a 6000 pounds investment, it's only six pounds a cow. But if you got 100 cows, it's 60.' (Farmer 10)

In this case study, there were no plans of making the use of the camera a requirement since the scheme was outcomes-driven and wanted to let farmers decide how they achieve those outcomes. However, not requiring the use of the technology also introduced the possibility of penalising some farmers over others, if some were to use automated data collection whilst others would provide data manually. As one farmer said:

> 'If it's not a requirement for everybody to have it, then yes, you have the worry that you're going to be penalised compared to somebody else because of different methods of data gathering, I guess.' (Farmer 9)

Data reliability

Doubts were also raised regarding whom the technology was aimed at benefiting. One farmer mentioned that whilst the tool was useful to pick up lame cows, it could also penalise farmers who may not be able to sell their milk if their numbers fall outside of the schemes' deemed appropriate range. This is particularly true if the system lacks accuracy, highlighting the importance of building farmers' trust in the technology (e.g., through adequate validation). One farmer mentioned how inadequate scoring by the camera at the start of the project impacted their trust in the technology as a way to provide data to milk buyers. They said:

> 'I wasn't convinced when it was first actually working and things. It was very, very harsh scoring. It was saying half my herd was lame, and I was thinking well, you know, no one was ever going to use this technology. They may use it for management, but they're never gonna use it for the milk contract because it's gonna make you look terrible.' (Farmer 10)

Complacency

Another risk of automating lameness and BCS data collection highlighted by some stakeholders was that of potentially neglecting the value that the technology may have in terms of improving animal health and welfare management. As one of the technology developers mentioned, there was a risk that farmers would not get the real value out of the system if they only considered it as a way to save time. They said:

> 'The value of the data, really, is preventative. You know, preventative lameness or preventative body condition score loss. I think, if people are just buying it and it just saves them doing manual scoring then, it's a part of the tool, but it's not the important part. That's the danger.' (Developer 2)

Similarly, a farmer also raised concerns about the risk of becoming complacent about lameness, making farmers pay less attention to mobility. They mentioned the possibility of farmers relying on the data indicating whether they fall into the appropriate range as defined by the assurance scheme, as opposed to focusing on how lameness may impact the welfare of their herd. On this, they said:

> 'It could be the risk of, you think, oh, my mobility scoring is quite good, I don't need to look at it as much. Maybe there's a risk of you being too relaxed about it (...) you could become complacent having it there.' (Farmer 10)

Discussion

This study investigated farmers' and other stakeholders' perceptions of the use of a digital camera to automate mobility and body condition scoring in the context of farm assurance schemes. Though there is a general discussion of the potential impacts of DLTs on animal welfare in the wider literature (Schillings et al., 2021; van Erp-van der Kooij and Rutter, 2020), research into stakeholder perceptions of automating aspects of animal welfare assessments is much more limited. This is, in part, because most academic research into the application of technologies such as artificial intelligence (**AI**) does not focus on practical real-world applications on-farm (Fuentes et al., 2022). In the context of using the camera to automate mobility and BCS, which represent important animal welfare indicators and are often measured as part of welfare assessments (Roche et al., 2009; Whay & Shearer, 2017), there were perceived benefits and risks. Reflecting on our findings and the contribution of this study in the context of existing literature, we focus the discussion on four broad interlinking themes – data ownership and use, agency, efficiency, and consumer trust. A key overarching point highlighted in the wider literature on farm digitalisation (see e.g., Klerkx, Jakku and Labarthe, 2019; Fielke et al., 2022), and reinforced in this study, is the double-edged potential of digital farm technologies. In our study, impacts could be positive or negative depending on how DLTs are implemented and used in the context of automating some aspects of animal welfare assessments, and we seek to integrate this dichotomy throughout the following paragraphs.

Data ownership, consistency, and fairness

Stakeholders in our study discussed several issues related to the data captured by the camera. Positive sentiments concerned the potential ability of the camera to ensure consistency of the data collected, reducing the subjectivity associated with human inspections. Farmers especially thought that improved data consistency would increase the fairness of data collection processes (i.e., collection of BCS and mobility data), ultimately rewarding their positive management activities. Farmers had highlighted the possible discrepancies between reported and actual lameness prevalence in the UK, particularly considering the significant pressure they can find themselves under. It is known that farmers tend to underestimate lameness levels, and the subjective nature of such measures means that differences in assessments can subsist between different mobility scorers, especially when assessing slightly lame cows (Leach et al., 2010; Winckler & Willen, 2001). However, farmers expressed conflicting concerns that the data collected may not always be reliable and thus the camera could unjustly penalise farmers. Additionally, the idea of the data being directly accessible to third parties was a concern to some farmers, who were worried about potential repercussions if the system was faulty.

Stakeholder concerns over the reliability and ownership of data collected by digital farm tools have been expressed in numerous studies interrogating the 'promises of precision' (Carolan, 2018; Rotz et al., 2019; Kuch, Kearnes and Gulson, 2020; Forney and Epiney, 2022), though not specifically in the context of automating welfare assessments. Wiseman et al. (2019) undertook a survey focused on data ownership of 1000 Australian farmers from a variety of sectors, including livestock enterprises. More than half of these respondents had little trust in technology providers maintaining data privacy or not sharing it with third parties. Just 9% said they had a good understanding of terms and conditions regarding data ownership. In a different survey of 880 Australian broadacre farmers, only 34% regarded themselves as the primary beneficiary of data collection (Zhang et al., 2021). Of most relevance to our study, a survey of 1500 livestock farmers in Wisconsin around the adoption of digital technology identified farmer concerns over data privacy and security as one of the most significant barriers (Drewry et al., 2019). Similar views shared by grain farmers in Australia led (Jakku et al., 2019, p.7) to pose a question on behalf of farmers: 'If they don't tell us what they do with it, why would we trust them?'. Some scholars even wondered whether increased data capture is being used to increase corporate control over farm decision-making (Brooks, 2021; Forney & Epiney, 2022).

Since we have only begun to capture stakeholder concerns over the use of data collected in the context of farm assurance, little research has been conducted to identify mitigation measures. It may be useful, therefore, to look at proposed solutions to data privacy and security being proposed across digital livestock supply chains. For example, Blagoev and Atanasova (2022) identify blockchain as a technology to keep digital livestock data safe, whereas Abbasi et al. (2022) developed a distributed ledger technology to ensure verifiability, traceability, and secure data sharing in a beef supply chain. Solutions should ideally be co-developed with stakeholders across the supply chain to build trust and ensure that their concerns are properly addressed (Rijswijk et al., 2023).

Agency

Automating welfare assessments as part of an assurance scheme may be voluntary or imposed by a retailer or other organisation. Whilst, in this case, the assurance scheme did not intend to make the use of the camera a requirement, stakeholders in our study expressed conflicting views on whether the use of the camera ought to be made compulsory in the future. On the one hand, farmers thought that compulsory adoption would level the playing field, ensuring that all farms were being held to the same standards. However, concerns over cost implications and the lack of control over both the decision to impose requirements and the subsequent operation of the camera were also raised. Therefore, if the use of DLTs were to become a requirement, there are two key issues to consider: cost implications and impact on farmer autonomy. To guide the possible response to the conundrum of whether to impose the use of DLTs to automate assessment, lessons from the wider literature could be taken up. Though these lessons are not specifically generated in the context of automating welfare assessments, several studies have explored the issue in relation to the adoption of other DLTs. In a study conducted by Lima et al. (2018) on the use of EID tags in sheep farming, it was found that external pressure to adopt technologies negatively impacted adoption and farmers' trust in technologies, and farmers were more likely to consider technologies as an extra burden. The study highlighted that without general approval by the sheep industry, making the use of technologies a legal requirement could exacerbate negative perceptions towards their use and increase feelings of pressure among farmers (e.g., external pressure from the government). Another study on the use of EID tags also highlighted that cost could represent an important barrier to requiring the use of DLTs (Kaler & Ruston, 2019).

An overall message from our study and other research is, therefore, that potential intentions to automate animal welfare assessments through the compulsory use of technology should be planned carefully; ideally involving users from the outset, ensuring that their voices are heard, and providing support to those who are least able to adopt DLTs due to cost restrictions and other factors e.g., lack of digital skills.

Efficiency

Our study considered the use of a specific DLT in the context of automating welfare assessments, which is worthy of closer scrutiny about efficiency. Existing literature suggests that the primary motivation for considering DLTs as a useful way to automate welfare assessments is the potential to shorten the time taken to conduct these assessments and to replace subjective manual evaluations (Stygar et al., 2022). A recent review argued that 'the potential to develop ITs [information technologies] for welfare assessment is high' (Larsen et al., 2021, p.17). However, many of the potentially useful technologies are not appropriately validated (Fuentes et al., 2022; Gómez et al., 2021; Larsen et al., 2021; Stygar et al., 2021). Stakeholders in our study agreed with both points; that the camera offered the potential to reduce the time and costs of hiring human experts who may provide more subjective welfare assessments than the camera, but only if it performed accurately.

Negative consequences on animal welfare may also be observed if assessments are based on potentially flawed data, as this may lead to poor management decisions. Whilst one of the perceived benefits of the camera was the potential to provide farmers with more frequent and precise information on lameness prevalence and body condition scoring, improvements to animal welfare still depend on how farmers decide to make use of that information. Whilst some farmers may become more proactive e.g., in lameness management (as observed in this study), concerns were expressed regarding the potential of farmers becoming complacent towards lameness if the technology was used more as an assurance tool and to tick boxes, as opposed to informing management to minimise welfare issues on farms.

In addition, like the camera used in the case study, most currently available technologies are focused on animal health and productivity parameters, as opposed to helping promote positive aspects of welfare (Schillings et al., 2021). As DLTs have not cur-

rently been widely applied in practice, the impacts of the use of DLTs on animal welfare are still unclear (Dawkins, 2021), and care should be taken in ensuring that this focus on health and productivity parameters should not come to define animal welfare (Buller et al., 2020). Historically, the focus of animal welfare has often been on reducing negative experiences such as pain or stress, though animal welfare scientists increasingly promote the need to consider the importance of positive affective states (Boissy et al., 2007; Lawrence et al., 2019).

Overall, if automated technology was ever to be used to determine levels of welfare on farms, it is crucial to validate whether DLTs offer more accurate results than manual scoring; especially as technologies and associated algorithms are developed by humans and may or may not always involve other experts (e.g., animal scientists) in development. It is also important to understand what impact DLTs will have on farm management and animal welfare on the farm. This will require research which observes and measures on the ground how automation technologies are used on farms, including how stakeholders (e.g., farmers, assurance scheme workers, retailers) act on the data and what impact this has on animal welfare.

Consumer trust

In theory, academics have argued that 'implementing remote sensing, biometrics and AI for livestock health and welfare assessment could have many positive ethical implications and higher acceptability by consumers of different products derived from livestock farming' (Fuentes et al., 2022, p.68). DLTs could feasibly reduce potential scoring subjectivity and help enhance consumer trust in labelling systems by allowing the provision of detailed information on animal welfare parameters (Ingenbleek & Krampe, 2022; Stygar et al., 2022). As long as the technology worked effectively, stakeholders in our study thought that using the camera to automate welfare assessments could enhance consumer trust. Studies have shown that despite labels being the primary source of information about animal-based products, many consumers do not trust them (Ingenbleek & Krampe, 2022; Vanhonacker et al., 2010). In our study, allowing consumers to access relevant welfare-related information collected by the camera was considered a helpful way to improve consumer trust by being able to provide evidence of compliance with animal health and welfare standards and demonstrate efforts that these are being adequately monitored. This, in turn, could help consumers make choices in agreement with their personal values (Hoogland et al., 2007).

Whilst our stakeholders' perception of likely enhanced consumer trust concurs with similar arguments put forward in the literature, the extent to which trust may be improved remains uncertain. Animal welfare labelling from a consumer perspective is a complex phenomenon, and there are uncertainties as to whether and how the data generated by DLTs could provide reliable and validated information, and how this may reach consumers (Ingenbleek & Krampe, 2022). This highlights the need to further explore consumers' acceptance of DLTs and the possible impacts technologies may have on their behaviour (Krampe et al., 2021), particularly since improvements to animal welfare can be driven by consumer demand (Thorslund et al., 2016).

Conclusion

Discussions with stakeholders involved in a trial to automate mobility and body condition scoring in the context of farm assurance schemes revealed important perceived benefits. This includes the potential to help build consumer trust by increasing transparency, making welfare-related data readily available, and helping farmers manage their livestock more efficiently. By providing more frequent and consistent data, the technology was also considered a way to promote fairness across the dairy industry. However, concerns were raised regarding the possibility of making the use of DLTs in the context of farm assurance schemes compulsory in the future, especially considering the current lack of clarity around data ownership and reliability. Unreliable data could unjustly penalise farmers, especially if the data were made directly accessible to third parties. To promote the successful implementation of DLTs in this context, better clarity should thus be provided to farmers in relation to data governance. Solutions should also be in place to ensure the data generated is properly validated, evidence provided regarding its accuracy, and adequate support should be provided. The study revealed the complexity of DLT implementation in the context of assurance schemes and highlighted the need for more inclusive approaches to innovative processes; including farmers in discussions to better understand their perspectives and identify their concerns. Due to the relatively small number of interviews conducted in this study and the potential bias introduced when involving farmers that volunteered in this specific trial, more research should be undertaken to strengthen our understanding of the potential benefits and barriers to the use of DLTs in farm assurance schemes and provide appropriate guidance to maximise the potential of these technologies whilst mitigating the risks.

Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.animal.2023.100786.

Ethics approval

The research project has been reviewed according to the procedures specified by the University of Reading Research Ethics Committee, which granted ethical clearance for this project.

Data and model availability statement

None of the data were deposited in an official repository for reasons of commercial sensitivity.

Authors' ORCID

Juliette Schillings: https://orcid.org/0000-0001-7190-6553.
Richard Bennett: https://orcid.org/0000-0003-3226-8370.
David Rose: https://orcid.org/0000-0002-5249-9021.

Authors contribution

Juliette Schillings: Conceptualisation, methodology, investigation, data curation, writing – original draft preparation.
Richard Bennett: Supervision, writing - reviewing and editing.
David Rose: Supervision, writing - reviewing and editing.

Declaration of interest

None.

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