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Development of an animal health testing tool to reduce antimicrobial use on farms: perceptions, implications, and needs of Irish dairy farmers and farm veterinarians

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Abstract

Background The threat of antimicrobial resistance is triggering the need for behavioural change towards antimicrobial use on Irish farms. Newly introduced veterinary medicine regulations are mandating the restricted and more prudent use of antimicrobials in the animal health sector. The need to reduce antimicrobials has placed a greater emphasis on the importance of animal health testing, however, issues with current testing practices are affecting diagnosis and subsequent drug usage. There is potential for digital technologies to address these issues and reduce antimicrobial use on farms, however, for these tools to be successful, they would need to be developed in collaboration with future end users.

Results Using qualitative approaches (focus groups), this study engages with dairy farmers and farm veterinary practitioners to detail current challenges with animal health diagnosis and to explore the initial development of a rapid, on-farm animal health testing tool to address these challenges. Issues with timing and testing, the role of knowledge and experience, and veterinarian availability all affect the ability of farmers and veterinarians to diagnose animal health issues on farm. These issues are having negative implications including the increased and unnecessary use of antimicrobials. An on-farm testing tool would help mitigate these effects by allowing veterinarians to achieve rapid diagnosis, facilitating the timely and targeted treatment of animal illnesses, helping to reduce overall antimicrobial use on farms. However, engagement with end users has highlighted that if a tool like this is not developed correctly, it could have unintended negative consequences such as misdiagnosis, increased antimicrobial use, challenges to farmer-veterinarian relationships, and data misuse. This study outlines initial end user needs and requirements for a testing tool but suggests that in order to successfully design and develop this tool, co-design approaches such as Design Thinking should be applied; to mitigate future negative impacts, and to ensure a testing tool like this is designed specifically to address Irish dairy farmers and farm veterinarians' values and needs, ensuring responsible and successful uptake and use.

Conclusions Digital tools can be effective in reducing antimicrobial use on farms, however, to be successful, these tools should be designed in a user centred way.

Keywords AMR, Digital technology, Animal diagnostics, User-centred design, Design thinking, Behaviour change

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In the following quote, one veterinarian explains the consequences of how this happens already in practice.

> *Veterinarian 1: "so in general, when any of our farmers, when most of our farmers take milk samples and we culture them, we generally culture what's on the outside of the teat as opposed to what's in the milk because they don't do it cleanly. (…) they just get e-coli from the outside so that's very frustrating. So equally if they don't do it properly, we're going to get erroneous results, and then you start prescribing stuff that's just plain wrong, that would be unfortunate".*

One group of farmers identified that instead of helping them to reduce antimicrobial use on farms, the presence of this device could lead to farmers overusing antimicrobials, as one positive result from the test could lead them to seek out antimicrobials and blanket use them as a prevention tool.

> *Farmer 2: "I don't think that will help on a farm to limit antibiotic use because you'll say, 'yea I'm after diagnosing a calf here, give me enough stuff for 30' you know what I mean.*
>
> *Farmer 1: and I'll do the rest of them just in case.*
>
> *Farmer 2: ya you will like because you don't want the rest of them to get it (someone agrees) so you're going to go in there and you might think they have it and they haven't it so I'd say it will probably be, to avoid concerns, t'would be one of them anyway because you'd be over prescribed drugs like".*

Building on this point, they later go on to say that a tool like this could be a risk because you are self-diagnosing. However, farmers then go on to say that they do not think that they will ever be given that kind of control over antimicrobials.

Challenges to farmer-veterinarian relationship

Farmers say that this tool could act as a stopgap to veterinarian shortages in the country but question the impact that it could have on farmer-veterinarian relationships. In their discussions, farmers demonstrated a consideration of and interest in what veterinarians would think about this tool. Farmers queried whether veterinarians would view the tool as a threat or as something that might be positioned, in a way, to replace them. They also questioned whether veterinarians would feel that they are being "*skipped over*" if farmers used this device in their stead and only contacted them to get antimicrobials. However, the general accepted consensus was that even if farmers had the device, the veterinarian is still needed and involved. Veterinarians have a better understanding of the limitations of diagnostic tests and so farmers recognise that even if they (the farmer) had primary use of such a diagnostic tool, they would require support from their veterinarian to correctly interpret test results and advice on what to do next.

> *Farmer 11: "I'd say the vets are going to hate it because if it does work right then we won't need them at all".*
>
> *Farmer 9: "What's the vets thinking? Is it taking them out of work?"*

One group of farmers questioned whether a device like this might cause a strain or a tension between the farmer and the veterinarian if there is a discrepancy between what the veterinarian thinks the illness is and what the device says it is. This might call into question what the veterinarian will treat or at a more extreme level, the competency of the veterinarian. Some farmers initially agreed that it could be a problem and potentially damaging to a relationship that has been built up over years, however, farmers overall concede that the veterinarian will make the right call, and that in cases such as these, oftentimes, there is no such thing as a definitive answer. Veterinarians also agreed that they are not always right and are open to being wrong but that they could not imagine there being much difference in what they suspect from their clinical examination and what the device confirms.

Data use/misuse

Concerns regarding data use and data sharing surfaced during discussions. Veterinarians more so than farmers queried what happens with the data that is collected via the device, assuming that the gathered information will be sold off by the manufacturer; used to examine if veterinarians were prescribing antimicrobials responsibly and to produce national trends of antimicrobial use on farms.

> *Veterinarian 3: "I imagine a significant source of the income for these people is selling this information at the end of it, this is how they justify having it, everything is for sale now, any information is for sale (veterinarian 1 agrees)".*

Farmers were also concerned with how data would be used and queried whether it would be used for corporate gain by pharmaceutical companies. Farmers discussed the possibility that pharmaceutical companies could become affiliated with the device and ensure that the results of the device point them towards using their products.

User requirements

For this to be an effective detection tool, participants express a number of key user requirements including reliability of results and key design features.

Reliability and trust

Whilst participants expressed a positive reaction to the idea of a diagnostic tool, these sentiments were almost

always followed up by remarks of *if* it works, *if* the results are reliable, and *if* it can be trusted. User trust in results is vital to the success of the device, without which, the device will be totally dismissed.

> *Veterinarian 9: "You'd want to have confidence in it or else (…), you'd be throwing it away fairly quick".*

Farmers in particular expressed an apprehension and scepticism in regard to the trust of and reliability of testing, recalling past scenarios where questions surrounded diagnostic testing; for example, cases of false positives in cattle tuberculosis (TB) testing and with human Covid-19 antigen tests. Knowledge of these past failings further cement the need of farmers to have trust in not only the reliability of the testing, but in the *consistency* of accurate testing. It also consolidates the importance of and need for veterinarian involvement and intervention. As veterinarians understand diagnostic testing limitations, they could interpret potentially false negative or false positive test results. Therefore, as one farmer states, it would be more important to get veterinarians convinced that the device works and that they trust it. The importance of getting this level of trust by veterinarians is highlighted in the statement by one veterinarian below.

> *Veterinarian 7: "I don't know how you'd measure that confidence that you have in it. I suppose ultimately will it be 'oh this is too big a deal to get wrong I'll just send them to [the] RVL or I'll send the samples somewhere else'. You'd have to get to that level of trust that you're [as] confident in it that you are sending it away".*

General design features

Both farmers and veterinarians express similar needs in respect to how this device should be built for use in practice. Farmers in particular state that they would need the tool to be user friendly and straight forward. Both sets of participants indicate that the device should be made robust, rugged, and durable so as that it is not affected by ground conditions. Veterinarians especially stress the importance of durability, stating that there is a large cohort of farmers who you probably would not be able to build a device robust enough for, describing that farmers would have it *"thrown in a bucket in the pit of the parlour"*, or veterinarians would have it *"thrown up on the dash of the jeep"*. If the device is not built to satisfy user needs or to work in the environment in which it will be used, as this farmer puts it, the device will be totally disregarded.

> *Farmer 15: "If it's not built right, durable like and all that and it ends up that it's kind of going to be a shitty enough device in a years'time, lads will just [say] that's the end of that (emphasized) as a (…) product really so that's what could be a problem down the road (…)".*

Discussion

This research outlines the current issues with and barriers to animal disease diagnosis on Irish dairy farms. The biggest issue with diagnosis is inadequate testing which has negative associated knock-on effects including treatment delays, increased/unnecessary use of antimicrobials, and detriments to animal health. The research also gives insight into farmer and veterinarians perceptions of the current use of digital technologies for animal health, as well as their initial thoughts on the conception of developing an on-farm diagnostic tool to address aforementioned issues. As well as directly discussing the potential of this diagnostic tool, this research also opens a broader discussion on the implementation of digital technologies for animal disease diagnosis and testing.

Value of a diagnostic tool to reduce antimicrobial use and to alleviate workload

There is potential for development of a testing tool to alleviate some of the animal health challenges facing the agricultural sector in Ireland. The tool could bring value to the animal health sector by playing an important role in helping Irish farmers and veterinarians comply with and adapt to the rules and associated knock-on effects of newly introduced veterinary medicine regulations by supporting antimicrobial stewardship on farms. There is a requirement of veterinarians to prescribe antimicrobials more responsibly and research has found that a lack of access to rapid diagnostics is a key barrier to appropriate antimicrobial prescribing [12], and that there is a need amongst veterinary practitioners for faster animal health testing [22]. Farmers and veterinarians in this research have highlighted that a rapid diagnostic tool would address this requirement and other diagnostic issues identified in this study, by helping to achieve early diagnosis and enabling users to quickly identify what strain of an illness an animal has. This would facilitate the timely treatment of that illness, leading to more targeted and reduced use of antimicrobials on farms. Similarly, the tool could be used to quickly identify illnesses which do not require an antimicrobial (e.g., viruses), helping to reduce the 'stop-gap' use of what turns out to be unneeded antimicrobials. Additionally, it has been highlighted in this study that a testing tool would be useful in aiding farmers in the transition to SDCT practices on farm. These outcomes combined would help Irish farmers and veterinarians in addressing and combating AMR.

This technology can provide more information to farmers which can assist management practices on-farm. The

Irish dairy industry operates a seasonal calving system, making springtime one of the busiest times of the year on Irish dairy farms. Managing herd health becomes more of a challenge during this time as a more compact calving means more calves being reared in a shorter window, resulting in challenges such as increased disease pressure on farm. It is expected that calving time may become busier for farmers and veterinarians, as recently published Irish Cattle Breeders Federation (ICBF) figures show the 2022 average six-week calving rate increased to 66% (an improvement of 7% over the past 10 years), with the top 10% of dairy farmers calving 86% of the herd in the first 6 weeks [23]. If these trends continue to increase towards the industry target of 90%, calving time will continue to get busier, meaning managing and maintaining good animal health will become a more important and difficult task for farmers and veterinarians, especially as animals are housed indoors during this time period. Utilising an on-farm testing tool could alleviate disease pressure in these scenarios by enabling users to achieve early diagnosis and intervention, helping to prevent spread of disease to the rest of the herd. This device could also be used by farmers as a general decision-making tool to inform farm management and animal husbandry practices. For example, if the tool identifies widespread respiratory issues on farm, it could indicate that a vaccination programme should be implemented the following year.

Important considerations for a diagnostic tool

However, it cannot be assumed that the results from this testing device will always be acted upon correctly. Having a rapid testing tool like this has the potential to provide farmers and veterinarians with a greater degree of information and knowledge. Farmers in the current study identified a knowledge gap in their capacity to identify and treat certain animal health conditions and they anticipate that digital technology can close that gap. However, although this expectation exists, it does not necessarily mean that it will be met. Precision livestock farming technologies are developed with the premise that users will have access to more and better information, assisting with decision making [24]. Whilst digital technologies can offer potentially valuable information, it does not necessarily mean that users will completely understand or utilise it, highlighting the important but often overlooked difference between adoption and use. Whilst these tools are monitoring animals and generating information, it is important that users are monitoring this information, and acting on it appropriately.

Additionally, when using technology, there is a risk of misinformation and incorrect use of information, and concerns regarding the use of information. While the main aim and premise for developing this testing tool may be to reduce overall antimicrobial use on farms, the current study found that there is a risk that the tool could lead to an over-prescribing of antimicrobials; if the testing tool is inaccurate, or if the testing results are acted upon incorrectly by users i.e., the prophylactic use of antimicrobials. This would result in a possible mismatch between technology intention and outcome and re-emphasises the importance of accuracy of animal health diagnostic technologies. Participants in this research recognised that farmers and veterinarians could not be totally dependent on the results of a technology like this to make a diagnosis, therefore, a testing tool like this should be used as an aid or a support tool in a diagnostic work up. Using the tool in this way would increase trust of the device and mitigate possible misinterpretation of test results. This study also identifies concerns regarding how information and data from technologies will be used, and whether it will be used to benefit larger corporations such as pharmaceutical companies instead of, or at the expense of, the user (i.e., the farmer or veterinarian); an issue that has been of growing concern in the digital agriculture space [17]. It is also worth noting that farmers in this study highlighted that although they can use this technology as a tool to identify animal health issues on farm, they still want to consult their veterinarian for reassurance and advice on what steps to take next. This indicates that although they are gaining information from the device, farmers still value and want input from their veterinarian, consolidating the importance of the farmer-veterinarian relationship.

Development of digital technologies for veterinarian use

The current study highlights the importance of employing user-centred design in PLF as this approach to technology development can help to identify and alleviate such unintended consequences at an early stage. To overcome these potentially unintended negative consequences, Responsible Research Innovation (RRI) principles should be applied to future technology design. Underpinning the concepts of RRI (anticipation, inclusion, reflexivity, responsiveness) to technology design will ensure that future technologies will be conscious of and responsive to the concerns, needs, and expectations of key end users and society as a whole [16, 25]. This study has demonstrated the value of some of these principles as engagement with future end users (inclusion) has successfully identified needs, concerns, and potential negative impacts (anticipation) that an on-farm testing tool could have. We suggest that if this tool is to be developed for commercial use, technology developers and engineers should be responsive to the needs and concerns of farmers and veterinarians highlighted in this study. As well as this, technology developers should continue to engage

with end users in the tools future development, to continue to anticipate and be responsive to other yet unidentified problems and needs.

The testing technology has been identified in the current study to act as a decision support tool which could aid and alleviate some of the heavy workload and frustrations experienced by veterinary practitioners. Retention and recruitment of veterinary practitioners is a real area of concern in Ireland [26]. Veterinarian shortages are predicted to worsen in years to come with Ryan and co authors [26] finding that just over half of Irish veterinarians who responded to their survey ($n = 370$) are considering leaving their role within the next 2 years, citing issues of work/life balance as the top reason for them wanting to leave. The current research has highlighted some of the implications that these veterinarian shortages are having, including the impact it can have on veterinarian farm visits and subsequent diagnosis. Digital technologies can help address these issues. Within the agricultural sector, there is a focus on the narrative of digital technology development to address *farmer* labour availability concerns; to make the agricultural industry a more attractive occupation for new *farmer* entrants; promising an improved work life balance for *farmers*; and offering a means for *farmers* to manage animal health on farms [17]. However, there is less reported in the digital agriculture literature on the development of precision livestock farming tools which are aimed at veterinarians. We argue that similar sentiments and efforts that are being applied to develop technology to help farmers along should be applied to the veterinary sector.

This research has made an initial effort at developing digital tools for veterinarian use. Engaging with end users to situate the concept of this testing tool in context and working with them to imagine how this concept would be employed in a larger setting has been useful in establishing potential for and a need for the development of a rapid on-farm animal health testing tool. It has also been valuable in identifying initial user needs and primary requirements of farmers and veterinarians for a testing tool like this. Future research would benefit from building on these needs and requirements, and we suggest that co-design approaches should be used to further develop the concept of this tool. Such approaches include Design Thinking, an approach long established in other fields, but which is a relatively new but growing application of design in the agricultural sector. Design Thinking is an approach with represents a shift in attitude from designing *for* users to one of designing *with* users [27]. During the five-stage process, researchers, technology designers, and end users collaborate; with end users being placed at the core of the design and development process. Reflexive and iterative engagement with end users ensures that user needs and preferences are highlighted, and that products and services are specifically designed to address those values and needs. Design Thinking tools have been used recently in an agricultural context to design a geotagged photo app [13, 28], in the development of PLF strategies for arid grazing regions [29], and in redesigning dairy systems in New Zealand [30]. The authors therefore suggest that the use of similar approaches should be applied to the future design and development of animal health diagnostic tools.

Study limitations

We do not claim that the study findings represent the full range of experiences and viewpoints of all farm animal veterinarians and dairy farmers in the Republic of Ireland. As the main recruitment strategy for farmers was via agricultural advisors, we can assume that the farmers at the focus groups were actively involved in information seeking behaviour. The participating farm animal veterinarians actively put themselves forward for participation in this study, therefore can be considered to be actively involved in research and innovation development. Responses therefore may not reflect the opinions of the majority of Irish farmer and farm veterinarian populations.

Conclusion

The threat of AMR coupled with newly introduced veterinary medicine regulations are placing Irish farmers and veterinarians under increasing pressure to reduce antimicrobial usage at farm level. Digital technologies can support farmers and veterinarians in reducing antimicrobial use on farm and this study has been successful in exploring the potential of a rapid on-farm animal health diagnostic tool to achieve this. Applying a user centred design approach to the development of this tool has been successful in identifying initial user needs and requirements for a testing tool. However, as well as identifying benefits, engagement with future end users has found that improper development could have unintended negative impacts such as misdiagnosis, increased antimicrobial use, and issues of adoption. Therefore, in order to mitigate future negative impacts, and to ensure the successful development and adoption of an on-farm testing tool, co-design approaches such as Design thinking should be applied to its design and development.

Abbreviations

AMR	Antimicrobial Resistance
WHO	World Health Organisation
EU	European Union
BDCT	Blanket Dry Cow Therapy
SDCT	Selective Dry Cow Therapy
RVL	Regional Veterinary Lab
PLF	Precision Livestock Farming

TB	Tuberculosis
ICBF	Irish Cattle Breeding Federation
RRI	Responsible Research Innovation

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
KMG, AR and TR conceived the study. KMG collected and transcribed the data, performed data analysis, and wrote the initial and successive drafts of the manuscript. AR, EK, and TR reviewed and edited successive drafts for subject matter content and clarity. All authors approved and read the final manuscript.

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Availability of data and materials
The dataset used in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was granted ethical approval by the Human Research Ethics Committee of University College Dublin (Research Ethics Reference Number: LS-LR-22-203-McGrath-Russell).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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