Project Report Project No. 61100049

Rapid Evidence Assessment: Factors Affecting Suckler Cow Efficiency, Profitability and Sustainability

Ryan Douglas[1] and Harvey Blackmore[1].

Reviewed by Sarah Wynn[1]

[1]ADAS, Battlegate Road, Boxworth, Cambs CB23 4NN

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Contents

1. Executive Summary

This report was commissioned in response to the challenges facing the UK suckler beef sector. Rising input costs are putting increased pressure on profitability, while farmers are under pressure from retailers and consumers to reduce their environmental impact. In particular, concerns about the climate impacts of beef production are negatively impacting on the reputation of the sector. Statutory targets, including the requirement for the UK to reach Net Zero greenhouse gas emissions by 2050, and increasing requirements from the supply chain for beef produced with low greenhouse gas emissions necessitate that farmers make improvements to their production systems. Adopting farm practices that improve productivity will help to not only meet these environmental challenges but also to improve profitability. For this to happen requires that farmers and advisors have a clear picture of the evidence of these practices to enable effective decision making.

The outputs of this research will enable farmers to improve their on-farm practices as it provides practical advice on techniques that will boost productivity, profitability and minimise environmental impacts. It gathers and provides insights and robust evidence to support and protect the reputation of the beef sector.

This project uses a rapid evidence assessment (REA) approach to determine the productivity, profitability and environmental impacts of several practices. An REA is a method of quickly collating and analysing the evidence base on a particular subject, by being limited in size (number of papers) and/or scope (metrics assessed). We investigated the impact of each practice on productivity metrics (no. calves weaned, average weaning weight, etc.), profitability metrics (added value, reduced inputs, etc.) and environmental metrics (GHG emissions, air and water quality, soil health and biodiversity).

In total, 16 practices were identified and assessed, across four categories: genetics and breeding, calving and fertility, feed, and management. For practices where sufficient evidence was identified, a narrative summary was produced, summarising the impacts across the main metrics, and presenting information in a farmer-facing format covering what the practice is, what best practice looks like, where it is most applicable and how robust the evidence base is. For practices where there was limited evidence, a brief discussion was provided, summarising what the practice is, what the evidence gaps are and how they might be filled. Health was excluded from this REA to constrain the scope of the project.

This process provided a review of a broad range of practices that can be implemented in the suckler beef sector. Eight practices were found to have multiple papers providing quantitative data with which to create a full narrative summary. Eight of the practices investigated in this REA were found to have limited quantitative data to support their value in improving productivity, profitability or environmental sustainability. Specific recommendations on how to address the evidence gaps for each of these practices is presented in section 6. While many of these practices are the subject of comprehensive reviews, with much discussion on the practice, the problem it is addressing and the barriers to uptake, there was a lack of quantitative evidence to be able to determine the impact on the outcomes investigated. A summary of the outcomes of each practice REA is presented in Table 1.

Table 1. List of practices selected for review, highlighting where there was sufficient evidence to complete a full narrative summary and where evidence was limited and recommendations were provided instead.

Genetics and breeding	Switch to (or cross with) breeds with improved productivity traits, e.g. mature cow size, feed efficiency, calving ease, others	**Full summary**
	Use a selection index to choose breeding females with a focus on relevant phenotypes e.g. pelvimetry	Recommendations
	Use a selection index to choose sires with a focus on calf productivity traits e.g. feed efficiency	**Full summary**
	Use genomic techniques	Recommendations
	Use artificial insemination and sexed semen	**Full summary**
	Breed for reduced mature cow size	**Full summary**
	Breed for reduced residual feed intake	**Full summary**
	Breed for improved calving ease	Recommendations
Calving and fertility	Calve heifers at 24 months	**Full summary**
	Regularly weigh breeding heifers to ensure optimal growth rates	Recommendations
	Score cow condition and adjust diet accordingly	**Full summary**
	Conduct a pre-breeding examination on stock bulls	**Full summary**
	Tighten block calving window	Recommendations
Feed	Match nutrition to animal requirements	Recommendations
	Use an alternative grazing pattern (mob/rotational versus set stocking)	Recommendations
Management	Appropriately timed culling	Recommendations

The discussion explored how these practices, both individually and collectively, could contribute to increased productivity and profitability, and reduced environmental impact. While these outcomes have been assessed separately, they are interrelated. Improving productivity on-farm will generally result in decreased costs and/or increased production, with corresponding impacts on profitability. Likewise, many practices that improve productivity, like reducing age at first calving, result in a reduction in the number of replacements required, which has knock-on environmental effects. Fewer replacements means less enteric methane, less manure (which reduces nitrous oxide, ammonia and nitrate leaching) and less feed requirement, resulting in lower embedded emissions.

Productivity

Productivity underpins many aspects of a suckler beef system, contributing to both profitability and environmental sustainability, and so this was the main focus of this review. Genetics and breeding play a crucial role in productivity, influencing calf growth rates, feed efficiency, calving ease and age at first calving. It was clear from the literature that the optimal choice of breed and herd breeding goals should be built around the constraints of the farm (e.g., forage quality, labour availability) and the intended market for calves (e.g., replacements in other herds, calves for finishing). There are many trade-offs within genetics, particularly between maternal traits (e.g. ease of calving) and terminal traits (e.g. calf growth rates). For example, larger calves at birth have higher growth rates resulting in greater weaning weights, but this comes at increased risk of calving difficulty. Some traits were identified as "win-wins", such as reduced residual feed intake which reduces feed consumption without impacting production, but there are barriers to adoption.

Calving and fertility were also very important in a productive suckler beef system. Ensuring adequate nutrition, which can be monitored through regular weighing and body condition scoring, enables heifers to calve at 24 months, while ensuring that older cows return to cycling quickly after calving in order to maintain the calving interval. Bull fertility was also identified as a key area, with evidence suggesting up to 30% of UK bulls were sub-fertile. Pre-breeding examinations were found to be a robust method of preventing the use of sub-fertile bulls and maximising cow productivity.

Profitability

Many practices that improve productivity will also improve profitability, through reduced wastage and increased output. However, relatively few direct studies of profitability were identified. This may be due to the fact that within each practice there was a range of different levels of implementation. For example, artificial insemination with sexed semen could be used on the whole herd to produce male calves, the best cows could be inseminated to produce only replacement females, or all heifers could be bred to produce females for reduced calving difficulty. This variation, coupled with the wide range of different farm systems and constraints, makes it difficult to determine precise quantitative assessments of each practice.

Environmental sustainability

As with profitability, there were very few studies identified that explored the impact of implementing different practices on environmental outcomes, although there were a few exceptions, particularly for direct methane emissions. In general though, practices that improve productivity allow the same level of production with a reduced replacement rate. Assuming the farmer maintains production but with fewer animals, rather than increases production in response to productivity gains, that will lead to an overall reduction in GHG emissions (from methane and manure), reduced ammonia emissions and lower levels of nitrate leaching from the farm, as all of these factors are linked to the number of stock on-farm. It is also possible that productivity gains could be used to increase stocking rates while maintaining the same level of gross emissions from the beef enterprise. This would result in a reduction in the emissions per kg of beef produced, also referred to as the emissions intensity of the product, which is desirable given current consumer and supply chain demands to move towards low carbon produce. At the same time, it is important to note that producers should remain cognisant of gross emissions as sectoral targets for emissions reductions will be a key consideration going forward.

Recommendations

Broad recommendations have been compiled from this review targeted at farmers, levy bodies, and industry:

- **Farmers:** Implementing practices identified in this review will enable an increase in on-farm productivity. An important recommendation is that improving herd genetics through targeted breeding offers several routes to improved productivity. There are resources available to support developing the best herd genetics, though farmers will have to apply these in the context of what is most appropriate for their farm type and constraints of the system (e.g. lowland and upland suckler herds require different genetics to one another). The report highlights several practices to help with decision making (e.g. body condition scoring). Incorporating these practices into standard practice on-farm, alongside an overall level of attention to detail, can bring about productivity gains. Some of the other reviewed practices have the potential to improve productivity, but there are currently insufficient resources to make these practicable for farmers to implement (e.g. breeding for reduced residual feed intake). For these, farmers need greater evidence and support in order to be able to implement. Farmers would benefit from having a greater understanding of a wider range of practices, both existing and new, and should look to the industry to provide appropriate resources in the future.
- **Levy bodies:** Given the clear productivity benefits resulting from some of the practices, the levy bodies should feel comfortable supporting the uptake of these. This could be through knowledge exchange activities and improving accessibility to the tools required by farmers (e.g. supporting the development of more accessible genetics databases). Encouraging uptake of practices requires building an evidence base; it is recommended that the levy bodies continue to commission research to build this evidence base for these practices for improving suckler herd productivity. Evidence-based improvements to productivity,

particularly where there are resulting environmental benefits, could be prioritised as there is an added benefit associated with promoting the sector to both farmers and the wider public.

- **Industry:** There is a continuing need for the development of technologies to support improved productivity in the suckler sector. Genetic techniques, such as the use of EBVs, provide an important means of breeding more efficient animals and driving productivity gains. Developing indices through increasing the data available on current traits as well as adding additional traits (e.g. residual feed intake) will further assist farmers. As farmers become more aware of the value of these approaches, and the levy bodies further promote them, there is a market opportunity for genetics companies to develop products to support improved genetics in the suckler herd.

Throughout the rapid evidence assessment process, several common evidence gaps were identified across all practices. The following recommendations aim to address these:

- **Holistic herd system model:** For any practices, the overall impact was difficult to determine, due to trade-offs with other traits (e.g. calf growth versus calving difficulty). Within the literature, practices were often studied in isolation, without taking into account these wider system impacts. The development of a modelling approach that captures the inputs and outputs of the system under a range of different scenarios, each with different sets of productivity parameters would help to understand the overall effect, which could then be linked back to the practices. Such a model could also incorporate profitability, GHGs and nitrates.
- **UK on-farm trials:** There was a major evidence gap across several practices in the lack of data generated on commercial UK farms. For some practices, an on-farm trial approach would be cheaper and more effective in generating an evidence base than rigorous academic studies, while also serving as a case study to support uptake on other farms.
- **Develop UK suckler beef selection indices:** Within some of the genetic sections, much of the evidence base came from Ireland, which has been successful over the last two decades in building a world-leading genetic database. This enabled the development of relevant selection indices that have been studied and proven to be effective. Working towards a UK-wide database would empower all stakeholders to improve the genetics of cattle in the UK.

Finally, this report provides a brief overview of a range of current and future technologies that could have substantial impacts in improving productivity, profitability and environmental sustainability of the UK suckler beef sector. Many of them require additional investment, both to finalise development and to promote uptake on farm.

2. Introduction

2.1. Background

The UK beef sector is facing several challenges at present, both financial and environmental. Changes to farm support payments following Brexit and increasing cost of inputs (fuel, feed and fertiliser) are putting increased financial pressure on the sector. In addition, these farms are also being asked to address a wide range of environmental challenges including reducing their impact on climate change, managing ammonia emissions to improve air quality, managing manures and nutrients to minimise negative impacts on water quality and enhancing soil health and improving on-farm biodiversity. At the same time, these farms need to maintain or increase productivity to ensure profitable production of high-quality, high welfare, low environmental impact beef to meet consumer and customer demands.

For all sectors, the climate impacts of agricultural production systems are coming under increasing scrutiny. In 2019, the UK pledged to meet Net Zero greenhouse gas (GHG) emissions by 2050. Following this landmark legislation, the National Farmers Union (NFU) set the goal that the UK agricultural sector would meet Net Zero emissions by 2040 through maximising efficiency of production, implementing changes in practice and introducing sequestration techniques as part of farmland management. The suckler cow herd, in particular, has been under increasing pressure to reduce GHG emissions, especially as retailers and other end users start to recognise that dairy beef production has lower climate impacts than suckler beef due to the emissions from the dam being allocated to her milk production rather than to her calf.

The UK red-meat levy bodies of Agrisearch, AHDB, Hybu Cig Cymru and Quality Meat Scotland (herein referred to as 'the levy bodies') recognise that although dairy beef has the potential for lower emissions than suckler beef there is still an important role for suckler beef to play. This includes importantly providing the genetics for crossing back into dairy beef as well as the role these cattle have in more extensive grazing systems where dairy beef animals would not thrive. Other key roles suckler beef animals have include; in conservation grazing, producing high quality beef from rough grazing, complimentary grazing alongside sheep, and providing nutrients in organic systems. The levy bodies have identified that there is a need to provide better evidence and support to this part of the industry to promote increased productivity and profitability, whilst also managing the environmental sustainability of production to ensure that the meat produced maintains its high quality and has minimal negative environmental impacts.

This project aimed to identify a series of practices to enhance productivity in the suckler beef herd (defined as management of the cow and her calf through to weaning) and review the evidence to determine the effectiveness of these practices at increasing productivity. While acknowledging health and disease as a key element in suckler beef production, health was excluded from this review to constrain the scope of the project. The review also attempted to quantify the impact on profitability and the direct and indirect impact of these practices on the wider environmental sustainability of the suckler beef herd, both at the farm and wider sectoral level. Once gathered, this evidence was evaluated and synthesised using the AHDB evidence framework and presented back as a series of narrative summaries targeted at a farmer audience. Where evidence or data was missing, this is highlighted alongside recommendations on what further research is required to fill these knowledge gaps.

This research will support farmers to improve their on-farm practices by providing practical advice on methods that will enhance productivity, profitability and reduce environmental impacts. It gathers and provides insights and robust evidence to support and protect the reputation of the beef sector.

2.2. Definitions

Productivity is defined as the ratio of outputs to inputs. Therefore, productivity can be increased by increasing outputs while maintaining inputs, maintaining output while reducing inputs, or a combination of the two. Productivity can also be increased by increasing or decreasing both outputs and inputs, such as breeding for reduced mature cow size, which decreases inputs proportionally more than outputs are decreased, leading to greater productivity. In this report, the main output of the suckler beef herd is weaned calves, while the key inputs include feed, fertiliser, energy and other consumables, as well as land and labour.

Profitability is closely related to productivity since there is a general increase in income with increased outputs and a general decrease in costs with decreased inputs. However, profitability can also be increased by creating more value per unit of output, such as by gaining access to more premium markets. Profitability in this report also considers wider financial pressures on-farm such as resilience and ability to diversify income.

Environmental sustainability considers several aspects of the natural environment that are affected by suckler beef production. In this report, the main areas of investigation are:

- Air quality (release of ammonia)
- Water quality (leaching of N and P compounds into waterways, as well as microbial contamination)

- Soil health (the ability of soil to perform ecosystem functions)
- Climate (the balance between emitted greenhouse gases and sequestered carbon)
- Biodiversity (the creation of new habitats, as well as the quantity and diversity of native flora and fauna on-farm).

With regards to climate impacts, it is important to note the difference between gross emissions and emission intensity. Gross emissions are the total emissions from a production system (e.g. a farm) and emission intensity is the quantity of emissions created in producing a unit of output (e.g. 1 tonne of beef). A farm can increase their gross emissions at the same time as reducing their emission intensities; this could be through increasing herd size (i.e. more cattle producing emissions) at the same time as improving the efficiency of production (i.e. more beef produced with less feed).

Since improved productivity is a key driver of profitability and many aspects of environmental sustainability, this report primarily focuses on productivity impacts. Practices were selected based on their ability to impact productivity, with the impacts on profitability and environmental sustainability assessed in parallel.

Production systems are referenced throughout this report. While there are many different types of suckler beef production systems, they are broadly categorised into two groups: intensive and extensive. **Intensive production systems** tend to use continental breeds (including their dairy crosses) and are generally suited to lowland systems with high quality grass or cattle in housing. These animals have high feed requirements, both in terms of quantity and quality, and often require more labour around calving compared to smaller native breeds. However, they produce calves with higher growth rates and heavier carcass weights. **Extensive production systems** tend to use native breeds which can utilise lower quality grass and so are often used in the uplands. They are faster maturing and so can calve sooner, and generally require less intervention and management during calving, however their calves reach lower carcass weights compared to intensive systems.

3. Aims and Objectives

Aim: Determine what practices are effective for improving the productivity, profitability and environmental sustainability of suckler cow production in the UK, both at industry and farm level.

Objectives:

1. Identify and provide evidence on how a range of practices can increase productivity, profitability and environmental sustainability of suckler cow production.

2. Present that evidence in a format that is accessible to farmers.
3. Identify gaps in the evidence and future technologies that would support future improvements in the suckler cow sector.

4. Methodology

A rapid evidence assessment (REA) is an approach to review an evidence base under time or resource constraints. An REA applies the same methodological steps as a more comprehensive literature review but makes concessions in terms of the number of databases searched, the quantity or type of evidence collected, or the amount of data extracted from each piece of evidence. This enables REAs to be delivered within a relatively short period of time while still providing a robust evidence summary (Collins *et al.*, 2015). Section 4.1 provides a summary of the REA methodology used.

The REA methodology was used to generate and evaluate an evidence base of academic and industry literature on the impact of different practices on productivity, profitability and environmental sustainability of suckler beef production. This evidence base was then evaluated using the framework outlined in section 4.1.5.

4.1. Rapid Evidence Assessment

The REA methodology consisted of the following steps:

1. Identify practices
2. Define search terms
3. Literature search and evidence collation
4. Evidence screening
5. Evidence evaluation

4.1.1. Identify practices

An initial list of practices of interest was provided by the levy bodies, which was revised to ensure that each practice had a clear action and measurable outcome. Additional practices were suggested following a review of key literature sources including:

- Suckler Beef Climate Scheme final report (*Suckler Beef Climate Group*, 2021)
- How farmers can reduce emissions (*CIEL*, 2022)

The list of practices was then discussed with the levy bodies and refined to a final list of 16 practices.

4.1.2. Define search terms

For each practice, search terms were created using an adapted version of the PICO methodology as described by James, Randall and Haddaway (2016) to enable consistent and comprehensive searching of each database for evidence that may support the impact of the practice. The search terms capture what the practice is, what the desired outcomes are (e.g. productivity), as well as restricting to certain evidence types (e.g. review papers). Inclusion and exclusion criteria were used to draw boundaries between what is and is not relevant to typical UK suckler beef systems, e.g. by excluding certain countries or production systems. An example set of search terms is shown in Table 2.

Table 2. Example set of search terms created using the PICO methodology.

Practice	Population	Intervention	Outcome	Include	Exclude
Regularly weigh replacement heifers	(review OR meta-analysis) AND (beef OR suckler) AND (heifer)	(weigh* OR size) AND (regular* OR frequent*)	(product* OR output OR efficien*)	UK, Ireland	Europe, US, Australia

4.1.3. Literature search and evidence collation

The search terms were then used to collate up to 20 pieces of literature (e.g. academic papers, reports, industry articles) for each practice, that may provide evidence that the practice has an impact on productivity, profitability and/or environmental sustainability. A tiered search process was used to maximise the quantity and quality of evidence (Figure 1). Initially, the search focused on review papers on the Web of Science platform, then Google Scholar and then the wider grey literature (e.g. government research reports), adjusting the search terms and/or database until enough evidence was collated. Where there was a lack of review papers, the search was expanded to individual studies to supplement the evidence base. Once the process had been completed or 20 papers had been reached, each paper was downloaded and catalogued using referencing software to ensure consistency of referencing. Throughout the search process, preliminary title screening was done to remove any papers that were obviously irrelevant and provide a higher-quality evidence base for subsequent analysis.

Figure 1. Summary of tiered search process.

4.1.4. Evidence screening

The aim of screening was to refine the list of up to 20 papers for each practice down to only those that were relevant. Previous REAs have shown that 3-5 high-quality meta-analyses can provide a robust evidence base for evaluation, with additional papers used to clarify specific points. Abstracts/summaries for each document were reviewed and each paper was scored using a traffic light system. Green papers were progressed to evaluation, red papers were excluded, while amber papers were screened by a second reviewer who assigned either a green or red score.

4.1.5. Evidence evaluation

Each paper that passed the screening process then underwent a structured evaluation process using the framework described in Table 3. For each piece of evidence, the reported impact of the practice on various outcomes was recorded, alongside metadata on the evidence itself, including the type of paper (e.g. academic review or grey literature) and type of study (e.g. lab or field). This metadata provides a proxy for the robustness of impacts reported in the paper. This information was recorded in an Excel based framework, with a column for each metric being assessed and a row for each paper being evaluated. A visual summary of this is provided in Table 3. Once all papers were evaluated, the scores for both the effectiveness of the practice and the quality of the evidence base were assessed using the AHDB evidence standards to determine the overall impact.

Table 3. Example framework document showing the types of headings that were used to identify the reference source and extract the information from each paper in the evidence base.

ID	Metadata		Productivity		Profitability	Environment
			Outputs	Inputs		
Practice no. Paper no.	Author Publication date	Paper type Study type	No. calves sold Avg. calf sold weight Avg. cow weight	Feed Energy Labour	Resilience Diversification	Air Water Soil GHG Biodiversity

4.2. Creation of narrative summaries

Where there were multiple papers providing quantitative evaluation of the impact of the practice across one or more outcomes, a narrative summary was produced, bringing together the evidence collected in the REA process. Narrative summaries are farmer-facing overviews of the practice and its impact, answering key questions on what the practice is, where it can be implemented, what the impact is and how strong the evidence base is. At the end of each narrative summary is a technical discussion which addresses in more detail some of the key themes discussed in the literature on the practice and, where relevant, provides additional recommendations to improve the robustness of the evidence base. Where there was insufficient evidence to quantify the impact of the practice, a shorter summary was provided, with a section making specific recommendations to address evidence gaps going forward.

4.2.1. Summary tables

Each narrative summary is accompanied by a summary table (see example in Table 4), which shows the impact of the practice across a range of key metrics, as well as information about the quality of the evidence base, costs and time associated with implementation and which production systems the practice is applicable to. Symbols are used to describe the overall result of the evaluation and an explanation of these is given in the sections below. These symbols and definitions are consistent with the Evidence for Farming - Draft Evidence Standards and allow for a semi quantitative comparison of the impacts and costs of different practices, as well as understanding the strength of evidence that supports these assumptions.

Table 4. Example narrative summary table.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
NA	++	+	–	–	NA	NA	NA	NA	NA	NA

Evidence base				
Quality	●●●○○		**Cost to implement**	£ – ££
Relevance	●●○○○		**Time to implement**	Moderate
Overall	●●●○○		**Time to impact**	Moderate – slow
			Suitable systems	All

Effectiveness

Effectiveness is assessed in terms of positive vs negative effect on the farm. With '+' indicating positive and '–' indicating negative. However, the evidence is often not as clear cut in the case of some practices (i.e. a given practice might not necessarily always be one way or the other), so the evaluation framework allows for some nuance in that assessment – see Table 5. Effectiveness was assessed across the three core focus areas of productivity, profitability and environment. Details are given below of the questions asked and what they mean.

Table 5. Evidence for Farming Initiative - Symbols used to quantify the effectiveness or impact of the practice on the core focus areas of productivity, profitability and environment.

–	**Evidence tends to show a negative effect.** The balance of evidence suggests that the practice has a negative effect, meaning the practice made things worse. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement (number and size of participating entities) in those studies.
0	**No effect.** The balance of evidence suggests that the practice has no effect overall.
+/-	**Evidence tends to show a mixed effect.** Studies show a mixture of effects and the criteria for 'tends to negative effect' or 'tends to positive effect' are not met.
+	**Evidence tends to show positive effect.** The balance of suggests that the practice has a positive effect. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement in those studies.
++	**Evidence shows consistently positive effect.** The evidence consistently suggests that the practice has a positive effect. This takes into consideration the number of studies showing positive and negative effects, and the levels of involvement in those studies.

Productivity

- Number of calves sold: Does the practice increase/decrease the number of calves sold? A positive effect was assumed to be an increase in calves sold.
- Average weaned weight: Does the practice increase/decrease the average weight of calves sold? A positive effect was assumed to be an increase in average weight of calves sold.
- Calving difficulty: Does the practice increase/decrease the rate of calving difficulty? A positive effect was assumed to be a decrease in the rate of calving difficulty.
- Cull cow weight: Does the practice increase/decrease the average cull cow weight? A positive effect was assumed to be an increase in the average weight of cull cows. (Note that this was considered in the context of increasing the amount of output [i.e. meat] within the parameters of that specific system. Weight needs to be balanced with other factors, such as bigger calves potentially resulting in a higher risk of calving difficulty. Also, to note the distinction between weight and size, as seen in the practice "Breed for reduced mature cow size", Section 5.1.4, decreasing cow size can be a target for improving productivity.)

Profitability

- Added value: Does the practice increase/decrease the average price per kg received for sold calves/cows? A positive effect was assumed to be an increase in average price per kg sold.
- Reduced cost: Does the practice increase/decrease input costs, e.g. feed, labour? A positive effect was assumed to be a reduction in input costs.

Environment

- Air quality: Does the practice increase/decrease ammonia emissions? A positive effect was assumed to be a reduction in ammonia emissions.
- Water quality: Does the practice increase/decrease nitrate leaching? A positive effect was assumed to be a reduction in nitrate leaching.
- Soil: Does the practice improve/degrade soil health? A positive effect was assumed to be an improvement in soil health.
- Climate: Does the practice increase/decrease greenhouse gas (GHG) emissions? A positive effect was assumed to be a decrease in GHG emissions.
- Biodiversity: Does the practice increase/decrease net biodiversity on-farm? A positive effect was assumed to be an increase in net biodiversity.

Other factors affecting the implementation of the practice

There were several other factors that were used to understand the impact of implementing the practice on farm. These factors aimed to identify the following:

- Cost to implement: How expensive is it to implement the practice? (See Table 6)
- Time to implement: What is the timeframe to implement the practice? (See Table 7)
- Time to impact: What is the timeframe to observe measurable results? (See Table 8)
- Suitable systems: Which suckler beef production system(s) is the practice relevant to?

Table 6. Evidence for Farming – Symbols used to represent the cost of implementing the practice on farm.

£	No new equipment or time constraints over and above existing business as usual (BAU) running costs.
££	May need some additional time for training or experiential learning to establish new practice, but once implemented this rapidly transitions into BAU running costs.
£££	As above, plus new equipment and capital costs for machinery and implements on farm.
££££	Major investment in new infrastructure on farm and/or loss of land utility/land use change that is greater than the normal rotation(s).

Table 7. Evidence for Farming – Quantification of the speed of change following the implementation of a practice.

Fast	Effective immediately, change within 0-3 months.
Moderate	Effective within 12 months.
Slow	Effective in longer than 12 months.

Strength of evidence

The final piece in the assessment table is the evaluation of the strength of evidence (see Table 8) which was separated into three parts.

- Quality: What is the quality/robustness of the literature reviewed?
- Relevance: How relevant are the experimental techniques to commercial farming operations?
- Overall: How confident are we in the overall result determined from the REA?

Table 8. Evidence for farming – Evaluation of the strength of evidence. Symbols used in the narrative summary tables and the explanation of what they mean.

	Very high	**High**	**Moderate**	**Low**	**Very low**
	●●●●●	●●●●○	●●●○○	●●○○○	●○○○○
Quality of literature	An extensive body of high-quality evidence reviews.	A developing body of high-quality evidence reviews.	Studies of the highest quality (randomised control trial equivalent) OR at least one high-quality evidence review.	Studies using quasi-experimental methods OR at least one moderate-quality evidence review.	High quality observational studies.
Relevance of context	As level 4, but with excellent contextual and Implementation insight drawn from high-quality studies and on-farm practice.	Includes evidence generated in farming and growing businesses with farmers and growers testing the practice.	Evidence generated in farming and growing businesses with the practice applied by professional researchers.	Evidence generated in research centre farming and growing facilities.	Evidence generated through laboratory research.
Overall	We can draw very strong conclusions about impact and be highly confident that the practice does/does not have the effect anticipated. The body of evidence is very diverse and highly credible, with the findings convincing and stable.	We can draw strong conclusions about impact and be confident that the practice does/does not have the effect anticipated. The body of evidence is diverse and credible, with the findings convincing and stable.	We can draw some conclusions about impact and have moderate confidence that the practice does/does not have the effect anticipated. The design of the research allows contextual factors to be controlled for.	We believe that the practice may/may not have the effect anticipated. The body of evidence displays significant shortcomings. There are reasons to think that contextual differences may substantially affect practice outcomes.	The body of evidence displays very significant shortcomings. There are multiple reasons to think that contextual differences may unpredictably and substantially affect practice outcomes.

4.2.2. Technical discussion and recommendations

Each full narrative summary is accompanied by a technical discussion. This is targeted towards a more technical audience and may provide more detail on the practice, discuss key themes identified during the literature search, potential barriers to uptake, evidence gaps and/or recommendations for future research.

Where there was limited quantitative evidence from within the literature base, partial narrative summaries were completed. These consist of a summary of what the practice is and what the limitations of the evidence base are, with a separate section highlighting ways in which the evidence base can be improved.

4.3. Outcome of REA

In total, 16 practices were assessed via rapid evidence assessment, covering genetics and breeding, calving and fertility, feed and management. Eight were deemed to have a sufficient evidence base to present a full narrative summary, while eight had such limited evidence that this was not possible and so background information and recommendations were provided instead (Table 9).

Table 9. List of practices selected for review, highlighting where there was sufficient evidence to complete a full narrative summary and where evidence was limited and recommendations were provided instead.

Genetics and breeding	Switch to (or cross with) breeds with improved productivity traits, e.g. mature cow size, feed efficiency, calving ease, others	**Full summary**
	Use a selection index to choose breeding females with a focus on relevant phenotypes e.g. pelvimetry	Recommendations
	Use a selection index to choose sires with a focus on calf productivity traits e.g. feed efficiency	**Full summary**
	Use genomic techniques	Recommendations
	Use artificial insemination and sexed semen	**Full summary**
	Breed for reduced mature cow size	**Full summary**
	Breed for reduced residual feed intake	**Full summary**
	Breed for improved calving ease	Recommendations
Calving and fertility	Calve heifers at 24 months	**Full summary**
	Regularly weigh breeding heifers to ensure optimal growth rates	Recommendations
	Score cow condition and adjust diet accordingly	**Full summary**
	Conduct a pre-breeding examination on stock bulls	**Full summary**
	Tighten block calving window	Recommendations
Feed	Match nutrition to animal requirements	Recommendations
	Use an alternative grazing pattern (mob/rotational versus set stocking)	Recommendations
Management	Appropriately timed culling	Recommendations

5. Practices with a robust evidence base

This section presents narrative summaries for practices where there was a sufficient quantity and quality of evidence identified within the literature base. In practice, this means at least one high quality review or multiple individual papers providing data on the impact of the practice on productivity, profitability and/or environmental sustainability.

5.1. Genetics and breeding

5.1.1. Switch breed

Switch to (or cross with) breeds with improved productivity traits, e.g. mature cow size, feed efficiency, calving ease, others

Narrative summary

This practice involves changing the herd genetics by replacing or crossing existing cows with those of a different breed. The impact will depend on the initial breed and the new breed selected, but for this narrative summary it was assumed that a purebred beef herd was gradually replaced with a dairy cross beef herd, as this is where the bulk of the evidence was available. In practice this could be done by crossing to breed own replacements or by purchasing new crossbred replacements and would probably be a gradual transition. The impact of switching, the cost and the evidence behind these assumptions is shown in Table 10.

The other approach is to switch from purebred continental (late maturing) breeds to native (early maturing) breeds. However, there was only limited evidence available on this approach and therefore although the approach is captured in the discussion, it is not captured in the quantification in Table 10.

Table 10. Impact of switching to crossbred (beef/dairy) cows with improved productivity traits on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1. Scores in brackets show potential indirect impacts as a result of increased production enabling a reduction in the replacement rate, although these scores were not quantified in the literature.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
+	++	+	–	–	NA	(+)	(+)	NA	(+)	NA

Evidence base			**Cost to implement**	£ – ££
Quality	●●●○○		**Time to implement**	Moderate – slow
Relevance	●●●○○		**Time to impact**	Moderate – slow
Overall	●●●●○		**Suitable systems**	All*

* Intensive lowland systems could accommodate a wide range of different breeds and replacement systems. Extensive upland farms may be more limited to native breeds.

1. What is the practice?

There are a wide range of breeds and replacement systems in the UK, each with their own merits. This narrative summary explores the impact of switching from either a purebred suckler beef herd to a dairy cross beef herd, or from purebred continental breeds to native breeds. In practice, this transition is likely to be gradual, replacing cows as they are culled from the herd with the new breed, either through purchasing replacements or by switching bulls.

Dairy cross cattle generally have higher milk yields, for feeding the calf, than purebred cattle, which contributes to improved calf growth rates and weaning weights. Purebred beef breeds are normally grouped into two categories: native and continental. Native breeds include Angus, Hereford and other native British breeds (also known as early maturing breeds), while continental includes breeds that originated from continental Europe – Charolais, Limousin and others (also known as late maturing breeds). The different breed types differ widely in a range of important characteristics, including age at sexual maturity, milk yield, growth rates, carcass conformation and others. The choice of breed and crossing system can therefore have substantial impacts on the suckler beef operation. This narrative summary compares the relative merits and disadvantages of different categories of breeds and crosses under different systems, although the ultimate decision should be based on the constraints of the individual farm and the requirements of the market they are selling into.

2. How effective is the practice at improving productivity?

The evidence review found that the key benefit of switching to a system with dairy cross dams was the increased milk yield for the calves, which supports increased daily liveweight gain. However, this comes at a cost of reduced cull cow weights. Compared to purebred beef breeds, dairy cross beef cows result in higher daily liveweight gains in calves (66-205 g/day across several studies), as reported by Sapkota *et al.* (2020), driven by higher milk yields (23-59% across several studies) and superior genetics passed on to the calf, supporting early calf growth. Dairy cross beef cows also have 14-19 kg greater weaned calf weights (McCabe, Prendiville, *et al.*, 2019; Sapkota *et al.*, 2020; McCabe *et al.*, 2021) and lower calving difficulty rates. Switching to a system with dairy cross dams may increase disease risk if replacements are bought in as opposed to bred on-farm, and the limited control over the genetics of bought in replacements should be amongst the factors considered alongside the benefits to productivity when evaluating the merits of this practice.

Native breeds have, on average, 8% lower calf birth weights (Sapkota *et al.*, 2020) compared to continental breeds, which results in reduced risk of calving difficulty. This is likely a key driver in higher median lifetime calf production (three versus two) since calving difficulty at first calving was found to decrease lifetime calf production by 30% (Nelson, 2016). However, continental breeds produced 21% more milk than native breeds (Sapkota *et al.*, 2020), which likely contributes to the improved growth rates of their calves – 75 g higher daily liveweight gain and 20 kg heavier weaning weights (Sapkota *et al.*, 2020).

3. How effective is the practice at improving profitability?

Although dairy cross beef cows produced heavier calves, purebred beef cows were significantly heavier (50-55 kg, McCabe *et al.*, 2020, 2021), with better body condition scores (0.27-0.31, McCabe *et al.*, 2020, 2021), resulting in higher cull cow carcass value compared to dairy cross beef cows (McCabe, Prendiville, *et al.*, 2019). In terms of feed efficiency, the results varied depending on the metric used (total dry matter intake, dry matter intake/kg calf weaned, etc.).

In a Norwegian modelling study (Asheim, Aass and Åby, 2021), native breeds were found to be more profitable than continental breeds in all climatic regions, with a 21 to 32% increase in gross margin, primarily driven by reduction in use of concentrates feeds.

4. How effective is the practice at improving environmental sustainability?

No papers were identified that explored the impact of this practice on the environmental metrics chosen, however we can infer some indirect impacts. Larger cows produce more total output and thus have greater overall maintenance requirements; however, cows of smaller mature size are proportionally more efficient. Where native breeds are used instead of continental breeds, this will ultimately lead to a system with lower age at first calving, reduced followers and faster time to slaughter. All of these will have indirect benefits for GHG emissions, ammonia and water quality through reduced enteric methane and manure being produced. Where there is a reduction in quantity of concentrates used, this will reduce embedded GHG emissions from fertiliser and fuel used to produce these commodities.

Native breeds such as Galloway, Highland and Longhorn, are also often used in conservation grazing systems because of their ability to utilise low quality forage. This enables the creation of meadows and other habitats, which can increase biodiversity.

5. Where does it work?

One of the key themes of the literature was that the optimal choice of breed and replacement strategy depends on the farming system. Upland farms, with lower quality forage are likely to be more suited to native breeds, while lowland farms, particularly those which have a homegrown supply of concentrates, may be more profitable in a purebred or dairy cross continental system. Further work is needed to understand which breeds are best suited to which systems. It is also important to consider what market the farm is currently supplying and whether there is a market for any potential new system, as some markets may have preference for certain breeds or characteristics associated with certain breeds.

It is also important to note that breed choice is not only determined by economics, but often by social reasons such as family history. This link to family history can be a significant barrier to change as there is a lot of social investment in the breeding of those cattle.

6. How much does it cost?

The costs of transitioning to a new breed will depend on the current breed, new system, and method of replacement. Either the existing bull can be replaced with a bull of the new breed which will gradually transition the genetics and/or cows can be replaced as they are culled or all at once. The costs below are indicative based on personal communications with a field agent from a large livestock trading co-operative (November 2022).

- Sale value of cull Limousin bull = £1,500 to £2,500
- Cost of purchasing average Angus bull = £4,000 to £4,500
- Sale value of cull Limousin cow = £1,200 to £1,300
- Cost of purchasing new Angus or dairy cross cow = £1,400
- Cost of rearing a dairy heifer (no data available for beef) = £1,800 (AHDB, 2016)

7. How can the practice be done well?

It is essential when looking at genetics in a suckler herd that they are considered both in terms of the farm environment and also the needs of the customer. Breed choice is influential across a range of parameters affecting the productivity and profitability of a suckler beef operation. It is important to understand your own farming system – the nutritional content of the grass, the cost of feed, the climate, etc. and then choose breeds that match that system. There is also substantial variation within breeds, so once a strategy has been selected it is important to purchase animals that have the best genetic merit for your system. Regardless of which breed or replacement system a farm uses, there is likely to be opportunity to improve productivity through optimising fertility (age at first calving, calving window), nutrition (matching feed to animal requirements), and herd management (optimal culling decisions).

Another aspect to consider is how the new genetics are brought onto farm. There are three main ways to achieve this: replace all cows at once, gradually replace cows with bought in replacements as they are culled or purchase a bull of the new breed to gradually change the genetics over time (especially where a crossbred system is desired). Each approach has different advantages and disadvantages: replacing more gradually is easier to manage from a cash flow perspective but takes longer to generate improvements. Gradual changes may also give time to transition into new markets.

8. How strong is the evidence?

A range of studies were identified that explored the differences between dairy-beef cross animals and purebred beef. One of these papers (Sapkota *et al.*, 2020) was a meta-analysis, presenting their own results as well as a range from within the wider literature. All available evidence showed consistent results for improvements in calf daily liveweight gain, weaned weight, cow milk yield, calving difficulty risk, but reductions in cull cow weight and cull cow BCS scores by switching from a purebred beef breed to a dairy cross beef breed.

Only three papers were identified that showed the impact of switching from continental breeds to native breeds, which limits the robustness of any conclusions. However, the evidence base is consistent in that native breeds produced smaller calves, with reduced incidence of calving difficulty, leading to increased lifetime production, albeit with slower growth rates and lower weaning weights. One paper based in Norway found that native breeds were more profitable overall in a range of regions.

9. Where can I find further information?

- A Teagasc report covers a range of information on suckler cow genetics, the differences in production traits between breeds, and the role of cross-breeding in improving suckler cow genetics.
- A Nuffield report from 2006 argues in favour of native breeds within the Scottish suckler beef context.

Technical discussion

The body of literature on this practice is primarily split into two types: papers that compared purebred beef (normally continental) breeds to dairy crosses of those breeds, and those that compared continental breeds to native British breeds. In both cases, the literature generally focuses on a small number of popular breeds, including Angus, Hereford, Charolais and Limousine. This limits the application of these results because, in reality, farmers are able to select from a wide range of breeds within both main types, as well as crosses between beef breeds, crosses with various dairy breeds, and various levels of back-crosses (e.g. beef crossed with dairy and subsequently crossed with beef).

It was clear from the literature that there is no optimum beef suckler cow breed, and that the best breed varies depending on the production system. In general, the literature supports the common view that native breeds are best suited to extensive systems and continentals to more intensive systems. Definitions for these systems vary, but are often based on the feeding regime, where extensive system use little to no concentrate feed. A few studies explored the suitability of different breeds to different production systems (e.g. Wetlesen *et al.*, 2018) although no quantitative data was provided.

This literature review provides strong evidence that dairy cross beef animals achieve superior calf growth to purebred beef animals (although at the cost of reduced cull cow value). Calf growth rate is a key profit driver of suckler beef systems and is determined by maternal traits (primarily milk production), terminal traits, as well as nutrition and other environmental factors (Sapkota *et al.*, 2020). There was broad consensus across the reviewed literature that dairy cross cows achieved higher milk yields, which is likely the basis for the increased growth rates observed in their calves. Sapkota *et al.* (2020) determined that each additional kg of milk production in the cow resulted in 47, 53, 51 and 55 g calf daily liveweight gain for dairy cross beef, purebred beef, native and continental cattle types respectively, resulting in 210 day-adjusted weaning weights of 9.8, 11.2, 10.7 and 11.6 kg.

McCabe *et al.* (2020) explored differences in feed intake between dairy cross beef cows and purebred beef cows. In absolute terms, dairy cross beef cows have higher feed intake due to increased lactation demands as a result of their dairy genetics. However, feed efficiency depends on how it is defined. They found varying results depending on whether feed intake was expressed in terms of feed intake per kg of weaned calf (no difference between breeds), milk yield per kg feed intake (dairy cross beef was more efficient) or residual feed intake (purebred beef cows were more efficient).

Overall, a key next step to better understand the interaction of different breeds and environments would be to conduct an on-farm study that compares the productivity of native, continental, native cross dairy and continental cross dairy, on both intensive and extensive systems.

The key recommendations for this practice are:

- For farmers to match their herd breed to their specific farming system
- For the levy bodies to support the collection of better data on the performance of different breeds under different production systems.

5.1.2. Use a sire selection index

Use a selection index to choose sires with a focus on calf productivity traits e.g. feed efficiency

Narrative summary

This practice involves using a suitable selection index to choose sires with traits that enhance the productivity of calves for meat production, such as growth rate, carcass weight and carcass quality. The table below shows the impact of using the Irish Cattle Breeding Federation (ICBF) Terminal Index. Within the literature, most studies quantified the impact of the selection index on finishing calves post-slaughter, rather than up to the point of weaning as is the scope of this work. The impact of sire selection, the cost and the evidence behind these assumptions is shown in Table 11.

Table 11. Impact of using a selection index to choose sires with a focus on productivity traits on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
NA	++*	NA	NA	++*	++*	NA	NA	NA	++	NA

Evidence base			**Cost to implement**	£ – ££
Quality	●●○○○		**Time to implement**	Fast – moderate
Relevance	●●●○○		**Time to impact**	Slow
Overall	●●●○○		**Suitable systems**	All

* Data up to slaughter, rather than weaning.

1. What is the practice?

Beef cattle traits can be split into two main groups: maternal traits (including ease of calving, milk yield, temperament, etc.) and terminal traits (growth rate, carcass conformation, weight at slaughter, etc.). The challenge is that these traits are often antagonistic, e.g. breeding for larger calves is associated with increased risk of calving difficulty. Selection indices are used to select for multiple traits simultaneously and are often grouped into either maternal (with a focus on maternal traits) or terminal (focusing on terminal traits). One of the most common terminal selection indices studied in the literature is the Irish Cattle Breeding Federation (ICBF) Terminal Index. This is an economic-based selection index designed to identify animals excelling genetically in expected profitability of their progeny at slaughter, and includes calving difficulty, gestation length, mortality, feed intake, carcass weight, carcass conformation and carcass fat. This practice explores the impact of using a terminal selection index to choose sires with enhanced productivity traits in progeny destined for meat production. The use of a maternal selection index to identify females as well as sires with suitable genetics to produce high profit replacement heifers is explored in section 6.1.1.

2. How effective is the practice at improving productivity?

The focus of the literature on the benefits of using terminal sire selection indices is primarily focused on the impact on the carcass weight and quality of finished calves. There is therefore a lack of understanding of the impact up to the point of weaning, which is the focus of this project. Assuming higher genetic potential for finished weight and quality is observable at weaning, then it may provide a useful proxy.

Two studies were identified that researched the impact of genetic merit (as determined by the ICBF terminal index) on carcass quality of finished calves. One study, by Connolly, Cromie and Berry (2016) grouped over 150,000 carcasses from animals out of the dairy and beef herds into four terminal index groups based on genetic merit. Compared to the lowest genetic merit group, the highest genetic merit group for animals out of the beef herd had 41.9 kg heavier carcass and improved carcass conformation. A similar study, by Kelly *et al.* (2020) reported that cattle in the high genetic merit group yielded a 25.05 kg heavier carcass, improved carcass conformation, a 3.22% better dressing percentage and 7 days less time to slaughter, relative to cattle in the lowest genetic merit group.

3. How effective is the practice at improving profitability?

Again, based on the finished carcass rather than weaned calves, the same studies reported improved carcass conformation scores (1.82 – 2.08 on a scale of 15) and reduced fat scores (1.24 – 1.7 on a scale of 15), as well as 13% higher total carcass value for high genetic merit cattle compared to low genetic merit. There was also reduction in feed intake of 0.46 – 0.63 kg dry matter intake/day, which will also have secondary effects on reducing input costs, although this was not quantified.

4. How effective is the practice at improving environmental sustainability?

One paper (Quinton *et al.*, 2018) explored the impact of improving terminal traits on whole herd GHG emissions. They reported a reduction in gross GHG emissions from the system of 0.018 kg CO_2e per breeding cow per year per € index. However, this was driven by increased offspring mortality which is not a desirable breeding goal. Use of the terminal index also reduced system emissions intensity by 0.021 kg CO_2e per kg meat per breeding cow per year per € index, which accounted for the benefit of increased meat production through improved carcass weight, conformation and fat levels.

5. Where does it work?

Selection indices can be used by any suckler beef system where the estimated breeding value (EBV) of the sire is known. It is particularly relevant to the use of artificial insemination, where there is a wide range of options for sires of different genetics, both proven and through genomics. However, where conventional breeding is used, selecting bulls of known profile using the traits highlighted in the index can drive an increase in the genetic quality of purchased bulls. Using a terminal selection index on herds that produce self-bred replacements may have undesired consequences on maternal traits, so is probably most applicable to herds where all calves are sent for slaughter and replacements are bought in. However, the genetics of the bought-in heifers should also be considered, although this is largely beyond the control of the farmer. Alternatively, producers can breed replacements from genetically superior cows and use a terminal cross on cows of lower genetic merit within the herd, depending on the size of the herd and the extent to which AI is used.

6. How much does it cost?

The main cost of sire selection is the difference in value between a high-genetic merit bull (with published EBVs) compared to an average genetic merit bull. The costs below are indicative based on personal communications with a field agent from a large livestock trading co-operative (November 2022).

- Cost of purchasing average Limousin bull = £4,000 to £4,500
- Cost of purchasing proven high-genetic merit Limousin bull = £7,000 to £10,000

A higher genetic bull may produce calves that reach finishing weight faster (due to faster growth rates) and therefore have lower costs, require reduced feed intake per day and/or achieve higher sale prices, although no information was available on these aspects.

7. How can the practice be done well?

To get the most out of using a terminal sire index, it is important to understand which traits are included, how they interact and how each of them impacts your production system. Farmers should identify the traits that are most desirable based on your system and select bulls that emphasise those while achieving a high overall index score.

8. How strong is the evidence?

There is good evidence to support the use of terminal genetics in production of efficient finishing cattle. However, there is a substantial knowledge gap on the impact of selecting for terminal traits on calves up to the point at weaning. Therefore, the productivity benefit to a suckler herd, where weaned calves are sold for finishing elsewhere, is less clear. Two papers were identified that confirmed an improvement in meat production and a reduction in feed during finishing, but those results do not necessarily apply to the suckler herd. Only one paper explored the system-wide impact of using a terminal selection index, although this was from a GHG perspective rather than directly productivity or profitability.

9. Where can I find further information?

- A Teagasc report covers a range of information on suckler cow genetics, what selection indices are and what traits they include, and relative benefits of using one index over another.

Technical discussion

There is sufficient evidence within the literature to state that cattle which have higher genetic merit as determined by the ICBF terminal index yield heavier, better-quality carcasses, while consuming less feed and in less time than those with low genetic merit. However, no evidence was identified that quantified the impact up to the point of weaning. In order to understand the implications of using terminal sire genetics to improve productivity up to the point of weaning it would be necessary to assess the impacts of the genetic changes at multiple points through the calf's growth, to determine if there were benefits to be seen prior to weaning, as well as at the point of slaughter.

All of the research identified used the Irish ICBF Terminal Index and Irish national herd data. While this is broadly applicable to the UK context, more work should be done to develop UK breeding indices based on the UK market. Within this review, there were no breeding indices identified that were specifically tailored to optimising profit from producing weaned calves, instead focusing on terminal traits or maternal traits of replacement heifers.

Selection indices only work when the sire's genetic merit is known and this is often not the case. Farmers typically buy bulls based on observed phenotypes (which could be artificially inflated due to nutrition or management regime) rather than underlying genetics. Genotyping cattle presents an opportunity to determine genetic merit and support decisions to improve herd productivity.

The key recommendations for this practice are:

- For levy bodies to develop a stronger understanding of the impact that genetic selection has prior to weaning,
- Develop UK-specific breeding indices that are specific to optimising profit from producing weaned calves.
- Farmers can reap the benefits of advancing the genetic profile of their herd by engaging with genomics and making use of a selection index to enhance on-farm productivity.

5.1.3. Use artificial insemination and sexed semen

Narrative summary

Artificial insemination is the process of artificially impregnating dams with semen from genetically superior bulls. Often, the semen is sex-sorted so that only male or female animals are born depending on the requirements (e.g. for replacements or finishing cattle). Table 12 shows the impact of using AI with sexed semen to produce male calves, in comparison to natural service.

Table 12. Impact of using artificial insemination and sexed semen to produce male calves on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
–	++	+/–	NA	++	–	NA	NA	NA	NA	NA

Evidence base			**Cost to implement**	££ – £££
Quality	●●○○○		**Time to implement**	Moderate
Relevance	●●●○○		**Time to impact**	Slow
Overall	●●●○○		**Suitable systems**	Intensive

1. What is the practice?

Artificial insemination (AI) is a technique that is already widely used in the dairy sector and involves artificially impregnating females with semen from genetically superior bulls with known traits. In the dairy sector, the most genetically superior cows are normally crossed with sex-sorted semen so that only female replacements are born. Sex sorting is a technique whereby X and Y sperm are separated based on differing amounts of DNA using flow cytometry (although other techniques are in development). This enables the production of semen that produces only males or only females with 90% reliability. AI has the potential to substantially improve productivity, particularly in more intensively managed systems since it would allow access to superior genetics that otherwise would be unaffordable for individual farms. Using sexed semen would provide additional benefits in that sires with improved maternal traits (at the cost of terminal productivity traits) could be used to produce female replacements, while sires with improved terminal traits could be used to produce male progeny for finishing.

2. How effective is the practice at improving productivity?

Quantifying the benefits of AI with sexed semen is challenging, since there are few case studies in the beef sector to rely on and there many factors at play.

AI with sexed semen can ensure that only male calves are produced, using sires with superior productivity traits. Male calves tend to have higher growth rates, greater carcass weight and improved carcass composition. However, male calves carry an increased risk of calving difficulty compared to female calves (Telford, Beard and Franks, 2003). The use of sexed semen has also been associated with reduced conception rates, typically 70-90% of that of natural service (Holden and Butler, 2018), although this can be minimised with good management practices like accurate oestrous detection, trained insemination technique, correct semen storage, etc. Technology also continues to develop to bridge the fertility gap between natural service and sexed semen.

Where female calves are produced, the effect will be more mixed, since decreased calving difficulty rates can balance with the reduction in conception rates. Using sexed semen to produce female calves can reduce calving difficulty rates by 20%, with less severe outcomes when calving difficulty does occur – male calf calving difficulty results in 57% higher mortality than female calf calving difficulty (Holden and Butler, 2018).

The use of sexed semen also increases the rate of genetic gain of the herd, by ensuring that replacement females only come from the highest genetic merit dams, which would have impacts on improved milk yield, weaning weights, fertility and other traits.

3. How effective is the practice at improving profitability?

As with productivity, the effects on profitability are difficult to quantify. Where male calves are produced there are likely to be fewer calves weaned because of reduced conception rates and increased calving difficulty risk, although this is balanced by improved carcass weight and value compared to female calves. Telford, Beard and Franks (2003) suggested that male calves were worth approximately 22% more per kg of liveweight at weaning than their female cohorts in lowland, upland and hill herds.

Additionally, an AI system requires additional labour at conception, which carries both a direct cost and an opportunity cost. For mixed beef and arable farms there is increased workload in the summer months (for a spring-calving herd) which may conflict with the arable enterprise.

4. How effective is the practice at improving environmental sustainability?

No papers were identified that explored the impact of this practice on the environmental metrics chosen.

5. Where does it work?

The challenge of implementing AI is that cows must be contained during the process and so it requires infrastructure, handling systems, additional equipment to store straws, increased labour requirements and a production system that facilitates bringing cows inside during this time. It is therefore most practical on intensive systems where there are existing cattle handling facilities and cattle are already housed for periods of time. It is much less practical in very extensive systems where labour is limited and there is currently limited infrastructure. There are also challenges in intensive systems with a mixed arable operation, since a spring-calving herd requires additional labour during the summer for insemination, which conflicts with the workload from an arable system.

6. How much does it cost?

It was assumed for this costing that shed and handling systems are already available, since the cost of these capital items is unlikely to be justified by the benefits of an AI system alone. The remaining costs would depend on how artificial insemination was carried out. The following costs assume a synchronised oestrous system followed by AI delivered by technicians and is provided through personal communications with an AI account manager, a commercial dairy and beef farmer, and is based on a herd of 40 cows (November 2022).

- Time to bring cows in three times to undertake oestrous synchronisation and prepare for AI = 12 hours x 2 staff = £240
- Treatments for synchronised oestrous = £8-10/cow
- Service technicians to AI cows = £20/cow
- Total cost for 40 cows - ~£600 per year

For comparison, estimated figures for natural service using a maternal bull are provided below (Laws, 2014):

- A bull producing 40 calves per year has a cost per calf of £27 if kept for 5 years. Assuming 36 calves per year this is approximately £972 per year. These figures include the cost of the bull less the cull value, plus annual maintenance costs.

7. How can the practice be done well?

The optimal use of AI and sexed semen depends on the farm system and market for cattle produced. The two main approaches will be producing replacement females for sale into other suckler beef herds and producing male progeny for finishing. AI can be used without sexed semen, but this incurs all the costs of setting up this system, but without the benefit of sexed progeny. Even when using AI, farmers must still select sires with traits that complement their production system (e.g. by selection indices). Overall, to make AI as successful as possible, the farm needs to be clear on what type of cattle they are producing and for what market, have the infrastructure and equipment required to carry out the practice with minimal labour costs and handling time, and be well trained in the technique to minimise the losses in conception rates compared to natural service.

There are a range of different ways that AI could be implemented on suckler beef farms. One of the most common approaches is to use sexed semen only on heifers to ensure easy-calving female calves in their first calving. If using AI on the whole herd, cows could be inseminated with sexed semen to produce only male calves and maximise production. Another approach could be to use sexed semen on only the most genetically superior cows and heifers to accelerate genetic progress in the maternal line if the best animals could be appropriately identified and retained each year. The approach will depend on the intended markets for the progeny (whether they are for slaughter or replacements).

8. How strong is the evidence?

There was a lack of evidence specifically exploring the impact of AI and sexed semen on UK suckler beef herds, with only two studies identified. Telford, Beard and Franks (2003) conducted a survey to understand existing AI practice within the UK beef sector and to assess opportunities and challenges, while Holden and Butler (2018) conducted a literature review on the benefits of this technology and provide a detailed discussion on the strengths and limitations. While these papers present some robust evidence on individual elements of an AI system (e.g. the impacts on conception rates, or increased growth rates), neither put this into a holistic context within a commercial farm system.

9. Where can I find further information?

- An article by The Cattle Site provides a practical overview of artificial insemination in beef herds.

Technical discussion

Telford, Beard and Franks (2003) conducted a large survey of UK suckler beef farmers and provide detailed discussion of farmers' attitudes and the potential barriers to increased uptake of this technology. The main barriers identified were:

- Insufficient labour, particularly in larger herds (over 70 cows).

- Cost, particularly in large herds where the cost of a bull can be spread over a greater number of cows. This emphasises the need to demonstrate clear financial benefits of using AI and sexed semen over conventional service.
- Poor conception rates, although this can be minimised through accurate heat detection and good insemination technique. New sperm-sorting technologies are continuing to bridge the gap between sexed and conventional AI.
- Lack of handling facilities, which was the main barrier for almost a third of respondents who do not currently use AI.

While some of these barriers will alleviate over time (e.g. increased uptake will cause costs to fall), others may be unavoidable and mean that AI remains unviable on some farms. There is little evidence of substantial progress since this study was published in 2003, while the barriers are likely the same. The average beef herd size in the UK (excluding Wales, data unavailable) is approximately 31 cows (AHDB, 2019b). Some of the barriers identified above may be more applicable to larger herds (over 70 cows), however, demonstrating the various benefits of using AI and sexed semen over conventional service is no less important when considering beef herds closer to the national average size.

The key recommendations for this practice are:

- For farmers to evaluate what the potential gains are from the use of AI for their individual beef systems, especially in relation to the pace at which genetic progress can be accelerated within the herd and the impact that this can have on productivity as well as profitability.
- Levy bodies to promote further work in this area to determine the impact of AI and sexed semen on UK suckler beef herds.

5.1.4. Breed for reduced mature cow size

Narrative summary

Breeding for reduced mature cow size involves selectively breeding replacement heifers such that they will be lower weight and thus smaller in size upon reaching maturity, to the point where they are at the optimum mature cow size for a given suckler beef enterprise. The optimum cow size will depend on the climatic environment, the production system in place, and ultimately the market within which the farm operates. The impact of selection for reduced mature cow size, the cost and the evidence behind these assumptions is shown in Table 13.

Table 13. Impact of breeding for reduced mature cow size on productivity, profitability, and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
NA	–	NA	–	NA	++	NA	NA	NA	NA	NA

Evidence base			**Cost to implement**	£ – ££
Quality	●●●○○		**Time to implement**	Fast – moderate
Relevance	●●●○○		**Time to impact**	Slow
Overall	●●●○○		**Suitable systems**	All

1. What is the practice?

This practice involves selecting for reduced mature cow size during breeding of replacement heifers while at the same time seeking to maintain or even improve reproductive efficiency and overall productivity. This practice is driven by the energy inefficiencies associated with body maintenance of the cow in the suckler beef operation. Mulliniks, Benell and Funston (2018) reported that 71% of the total dietary energy expenditure in beef production is used for maintenance, with 70% of the maintenance energy being required by the cows in the herd. As such, approximately 50% of the of the total energy expenditure related to beef production is used for maintenance of the cow.

2. How effective is the practice at improving productivity?

By aligning the mature size of cow with the individual production system to allow for optimum efficiency, on-farm productivity can be maximised. Morris and Wilton (1976) note that there is little variation expected in biological efficiency as a result of differences in size of cows, though it is possible that changing mature size may lead to substantial changes in requirements and outputs on an individual cow basis. Larger cows require greater quantities of feed and forage. Mulliniks, Benell and Funston (2018) outline that as mature weight increases from 450 kg to 650 kg for cows 90 days post-calving, requirements for intake, energy, and protein, all increase by 23%, 19%, and 13%, respectively. Continuing, they describe that for each additional 10 kg of body weight, approximately 60 kg of forage dry matter intake is required. By reducing mature cow size to the farm-specific optimum level, less feed and forage is required while productivity is maintained, potentially leaving room for increasing productivity, for example, by increasing stocking rates.

3. How effective is the practice at improving profitability?

With 50% of the total dietary energy expenditure in suckler beef production being attributed to maintenance of the suckler cow, and annual feed requirements for maintenance of the whole herd making up 50-75% of total feed requirements (Mulliniks, Benell and Funston, 2018), it follows that any reduction in maintenance requirements, and thus the quantity of feed required, would contribute to a reduction in costs. By reducing the mature size of the cow to optimum efficiency, profit margins can be improved through reduced feed costs with a smaller animal, and thus a lower maintenance requirement across the cow herd, without hampering productive output.

4. How effective is the practice at improving environmental sustainability?

This practice, by selectively breeding for reduced mature cow size, can have a direct impact on the environmental sustainability profile of the farm. A smaller mature suckler cow, that is operating at optimum efficiency, can directly contribute to emissions reductions on-farm when compared to a larger animal that consumes greater quantities of resources as well as emitting a higher level of emissions. This creates the potential to have more cows on farm, which would increase the number of calves produced and have lower GHG emissions per kg of beef produced. However, none of the studies reviewed specifically assessed the environmental impact.

5. Where does it work?

The efficacy of this practice is farm-specific. Arango and Van Vleck (2002) note that optimum cow size will depend on the production system in use. Further, Andersen (1978), as cited in Arango and Van Vleck (2002), suggested that there are no broad relationships between cow size and biological and economic efficiency, and that the optimal size will be determined by market requirements, and in particular by husbandry practices employed on the farm and environmental factors. A Norwegian study (Wetlesen *et al.*, 2018), based on observations made during an analysis of breed by environment interaction on suckler cow efficiency under various natural production conditions, emphasised how the natural production resources available should inform and ultimately determine the cow breed selected for a given suckler beef enterprise.

6. How much does it cost?

The costs associated with this practice are similar to those outlined in "Use a sire selection index" or "Use artificial insemination and sexed semen", depending on how the improved genetics are obtained. There would be savings based on reduction of feed intake, although this was not quantified within the literature.

7. How can the practice be done well?

Doing this practice well will involve closely aligning the mature cow size to the individual suckler beef farm such that it is within an optimal range for the given production system. One source identified the optimum mature cow weight for a typical UK production system to be in the region of 680 kg to 725 kg (AbacusBio, 2019). The same paper outlined that this range depends on the cost per unit of feed; production systems with the ability to sustain larger cattle (>700 kg) primarily on the grass forage available will tend to be closer to mature cow weights of 725 kg, while systems that do not generate grass forage volumes adequate to meet dietary requirements (e.g. hill and upland farms) with potentially high marginal feed costs, will tend to be better aligned to a mature size of cow closer to 680 kg. The authors also point out that the optimum weight will also be influenced by the weight at which penalties are applied to progeny carcases above a certain threshold.

By analysing the various costs of inputs and outputs in the beef enterprise, as well as market requirements, producers can determine the range within which they can achieve greatest efficiency, and thus identify the optimal mature cow size that will excel within this range.

8. How strong is the evidence?

There is consensus within the literature evaluated on the idea that the optimal mature cow size will depend on the individual farm and climatic environment, the production system in place, and the market within which the suckler beef enterprise operates. The evidence base for this practice was slightly limited, with just one of the five sources quoted originating from the UK.

9. Where can I find further information?

- A resource produced by Teagasc provides further information on suckler cow genetics and how improvements can be made within the herd.

Technical discussion

Acknowledging the fact that the suckler cow consumes a substantial amount of the dietary energy requirement on-farm, with 50% being required for suckler cow maintenance alone (Mulliniks, Benell and Funston, 2018), the benefits of breeding for a reduction in cow size to a farm-specific optimum level are clear. By reducing the cow size from that which is above what is required to maintain the same level of production, producers can effectively maximise productivity (via a reduction in feed inputs) and thus, profitability. There are also positive environmental implications associated with this practice, due to the reduction in embedded emissions linked to feed production, as well as having a smaller mature cow which will generate less methane, enhancing the sustainability profile of the farm.

The recommendations for this practice are:

- For farmers to consider the optimum cow size for their suckler beef operation and to evaluate what actions can be taken to move the current average cow size of their herd to reach that optimum.
- Although the concepts of maximising efficiency and identifying the optimal mature cow size are readily transferrable, industry bodies have a role to play in promoting further UK study to help strengthen the body of evidence currently available by making it more applicable to the UK context.

5.1.5. Breed for reduced residual feed intake

Narrative summary

This practice involves selecting for animals that exhibit genetically superior levels of feed efficiency, in an effort to reduce the amount of feed required on-farm, which in turn has benefits associated with productivity, profitability, and environmental sustainability. The impact of breeding for reduced residual feed intake (RFI), the cost, and the evidence behind these assumptions is shown in Table 14.

Table 14. Impact of breeding for reduced residual feed intake on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
+/−	NA	NA	NA	NA	++	NA	NA	NA	NA	NA

Evidence base			**Cost to implement**	£ – ££
Quality	●●●○○		**Time to implement**	Fast – moderate
Relevance	●●●○○*		**Time to impact**	Slow
Overall	●●●○○		**Suitable systems**	All

* Much of the work done previously has focused on housed conditions rather than at pasture.

1. What is the practice?

Residual feed intake (RFI) is defined as the difference between an animal's observed and predicted feed intake requirement over a given period. It can be calculated as the residuals from dry matter intake that relates to meeting primary energy demands such as maintenance, growth, and activity. The residual portions can be used to identify animals that deviate from their expected in-take, with lower (negative) values denoting greater levels of efficiency. It is a measurement of feed efficiency that has seen an increase in use, partly due to its conceptual independence from growth and body size (animal production), which makes it a useful concept to analyse the biological aspects related to the variation observed in feed efficiency between animals.

2. How effective is the practice at improving productivity?

From the literature examined, the evidence was strongest in relation to observed reductions in feed inputs. One Irish study (Fitzsimons *et al.*, 2013) found that high-RFI Simmental heifers fed grass silage consumed 9% and 15% more than medium and low-RFI heifers, respectively, with body weight, growth, and body composition all being equal between the groups. Another Irish study (Lawrence *et al.*, 2013) that fed ad lib silage for 73 days over winter to Simmental and Simmental x Holstein cows observed that the low-RFI group consumed 14% less silage than the medium-RFI group and 11% less than the high-RFI group, with body weight, growth, body composition, milk yield, calving difficulty and calf birth all being equal between the groups. In the same study, grass intake in the low-RFI group during summer grazing was 2% and 3% lower than the medium- and high-RFI group, respectively, though showed no statistically significant difference. When considering grass silage intake, these two studies have reported the effects of this practice to range from a 9% to 15% reduction in dry matter intake. Although more widespread and repeated findings would lend weight to these observations, these results are indicative of the potential efficiency gains to be made, even considering the more conservative finding of 9% difference in dry matter intake.

To quantify the impact of this practice further, an Australian study (Arthur *et al.*, 2001), as cited in Basarab et al. (2013), that conducted actual selection for RFI observed a direct yearly response of -0.125 kg dry matter per day due to selection, compared to the control. On the same point, another study (Alford *et al.*, 2006), also cited in Basarab et al. (2013), attempted to account for the reality that multi-trait breeding goals will be pursued by producers and, as such, a yearly response rate of -0.08 kg DM/day could likely be observed.

3. How effective is the practice at improving profitability?

Given that the outcome of this practice is directly linked with a reduction in the amount of feed required by the animal, while maintaining the same level of production, there is strong potential to improve profitability. According to one study (Nielsen *et al.*, 2013), cited in Kenny et al. (2018), a major economic factor that influences the profitability of beef production is the provision of feed in the diet, which constitutes as much as three quarters of total direct costs.

4. How effective is the practice at improving environmental sustainability?

Similarly to other practices that focus on reducing inputs while at the same time maintaining or increasing outputs, improvements made to on-farm efficiency will generally contribute to positive environmental outcomes. Simply by reducing the amount of resources required to produce the same amount of product alleviates the pressure on the environment to provide materials, as well as absorb waste. In the case of breeding for reduced RFI, selecting for genetically superior cows that exhibit greater levels of feed efficiency will reduce the overall feed requirement, thus reducing the emissions impact associated with feed production. Also, as enteric methane production is directly proportional to feed intake, reducing feed for a given level of production will reduce emissions per unit of product (Knapp *et al.*, 2014). One study found that there was the potential to improve feed efficiency and reduce enteric CH_4 emissions from cattle by 0.75% to 1% per year when compared to animals of equal weight, growth, and body fat that had not been selected for reduced RFI (Basarab *et al.*, 2013).

5. Where does it work?

This practice, as with other practices that involve genetic selection, can be implemented in a wide range of different suckler beef systems and climatic environments. Increasing feed efficiency within the herd reduces overall feed requirement on-farm and results in lower embedded greenhouse gas emissions from feed. These benefits will be particularly felt in scenarios where feed costs are high, where available forage is comparably limited or of lower quality, or where there is high demand for beef produced with a lower emissions profile. Given the current high costs associated with feed and sector targets for emissions reductions in the UK, there are a substantial number of suckler beef operations that would be faced with such scenarios, and that would benefit from increased feed efficiency.

6. How much does it cost?

Before this practice becomes accessible to farmers, estimated breeding values (EBVs) for this trait will need to be developed by genetics companies or others providing performance recording and genetic evaluation services. Once these are available, the costs associated with this practice will be similar to those outlined in "Use a sire selection index" or "Use artificial insemination and sexed semen", depending on how the improved genetics are obtained.

There would be savings based on reduction of feed intake, although this would depend on the type of feed and the reduction achieved. In the situation above where cattle were being fed silage for 73 days over winter low RFI cattle having reduced silage consumption of 11-14%, this would be equivalent to a saving of between £14 and £18 per head over winter – based on a cost of £60/t fresh weight for grass silage, with a DM of 30%, and consumption of about 30 kg fresh weight per day (for high RFI cattle) (AHDB, 2019a).

7. How can the practice be done well?

Once the EBVs for this trait are available, to do this practice well, incorporating selective breeding for reduced RFI as part of the wider breeding management plan will allow for the greatest genetic improvement that is applicable for the individual farm in question. Producers are currently limited in their ability to select for reduced RFI and an improvement in this regard is largely dependent on the development of EBVs by genetics companies and breed societies.

8. How strong is the evidence?

While the reduction in feed inputs has been observed in breeding for reduced RFI, the reviewed literature suggests that further experimentation is required to fill some of the gaps in the current knowledge base. Kenny *et al.* (2018, p. 1823) note that, despite numerous studies that analyse RFI spanning various breeds, production systems, and genders, there is a considerable lack of information relating to the biological regulation of the trait, particularly on the "contribution of key processes such as appetite control, gastrointestinal function as well as cellular energetics and metabolism". The authors proceed to outline that while the RFI trait has been demonstrated to be moderately repeatable across, and associated with different productivity related traits in confinement, there have been relatively few studies conducted to examine the same relationship at pasture.

9. Where can I find further information?

- There were no farmer-facing resources identified for this particular practice, as such, further relevant information on breeding for reduced RFI can be found in the review papers cited in this narrative summary (Basarab *et al.*, 2013; Kenny *et al.*, 2018).

Technical discussion

While the benefits of breeding for reduced RFI have been evidenced in the literature, so too have the gaps in the knowledge base. The accurate and prolonged measurement of feed intake at pasture, and associated costs, are key challenges that contribute to the lack of experimentation conducted in this area. Kenny *et al.* (2018) outline how further work in this area would strengthen the body of evidence already generated from experiments conducted in confinement.

Despite these knowledge gaps, producers can benefit from incorporating selective breeding as part of their management regimen, and in employing genomic selection to a greater extent they will be contributing to the predictive accuracy of these traits while at the same time raising the genetic profile of their herd. However, the EBVs required to select for this trait are currently unavailable. There is a need for EBVs to be developed so that these selection tools are available for farmers to use. Genetics companies are well positioned to achieve this, given their access to large numbers of bulls and resulting progeny data. Breed societies would also be well placed to develop EBVs for RFI, which could be valuable in marketing the efficiency of the breed. Given the multiple benefits of reducing RFI in profitability and environmental sustainability, without affecting productivity, there is potentially justification for a national measurement programme to develop EBVs for the benefit of the whole industry.

The recommendations for this practice are:

- For industry bodies to promote further work in this area to support the establishment of traits that can be selected for by farmers as part of their breeding management plans.
- This leads to the next recommendation, which is aimed at genetics companies and breed societies to conduct trials and to develop the EBVs, making them available to farmers for selection.
- Given that methane emissions are correlated with feed intake, levy bodies could incorporate that fact in making the case for prioritising this trait as a key area of focus in the light of emissions reduction targets.

5.2. Calving and fertility

5.2.1. Calve heifers at 24 months

Narrative summary

This practice involves effective management of several components that all contribute to heifers calving at, or near, 24 months of age. As evidenced in the literature, the age of first calving has a range of impacts on suckler beef productivity, as shown in Table 15.

Table 15. Impact of calving heifers at 24 months on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1. Scores in brackets show potential indirect impacts

as a result of increased production enabling a reduction in the replacement rate, although these scores weren't quantified in the literature.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
++	NA	0*	NA	NA	+	(+)	(+)	NA	(+)	NA

Evidence base				
Quality	●●●●○		**Cost to implement**	£-£££
Relevance	●●●○○		**Time to implement**	Fast
Overall	●●●●○		**Time to impact**	Slow
			Suitable systems	All

* Assumes crossing with appropriate sires and correct nutrition during pregnancy.

1. What is the practice?

The age at which heifers are calved can vary from 23 to 36 months and beyond, with varying outcomes that impact on productivity and profitability. Rather than being a practice in and of itself, it can be seen as the outcome of several practices that have been done well.

There are several factors that contribute to the age at first calving, such as the breeding and fertility management practices used on farm, nutrition, and health. Age at first calving has implications for costs of rearing, as well as the number of replacement animals required to maintain the size of the herd. As such, the age at which cows are calved at can have a substantial impact on the suckler beef enterprise. This narrative summary illustrates the relative impacts that calving at different ages has, ranging from 24 months to 36 and older, under different systems.

2. How effective is the practice at improving productivity?

Several studies have shown that earlier calving heifers produce a greater number of calves over their productive lifetime (Núñez-Domínguez *et al.*, 1991; Titterington *et al.*, 2015; Crosson, Woods and Keane, 2016; López-Paredes *et al.*, 2018). Further, one study observed that, up to seven years of age, the cumulative weight of weaned calves at 200 days old born from heifers that first calved at two years old was significantly greater ($P<0.05$) than that of three-year-old calving heifers (Núñez-Domínguez *et al.*, 1991). The evidence from the literature was clear on the benefits offered by aiming to calve heifers closer to two years of age. By incorporating this practice, suckler beef producers can achieve greater levels of operational efficiency.

3. How effective is the practice at improving profitability?

Reducing the age at first calving has been shown to have a direct link with increased profitability (Crosson, Woods and Keane, 2016; López-Paredes *et al.*, 2018).

One study conducted in Spain (López-Paredes *et al.*, 2018) found that in analysing 7,655 purebred Blonde d'Aquitaine cows from 301 herds, shortening the age at first calving from three years to two years of age had an effect of increased profit of €21.50, reduced heifer feeding cost of €17.70 and reduced production cost of €22.10 per slaughtered animal each year over the course of the productive lifespan of a cow.

Another analysis conducted in Ireland (Crosson, Woods and Keane, 2016) highlights the impact on profitability, citing an effect of €112/ha on net margin when calving heifers at 24 months versus 36 months, on a high output and high efficiency 40-hectare farm with 53 suckler cows.

4. How effective is the practice at improving environmental sustainability?

One of the papers that was identified (Crosson, Woods and Keane, 2016) remarked that the reproductive efficiency of the suckler cow herd (including, amongst other things, age at first calving) influences the environmental impact of suckler beef, with research farm systems (operating at higher levels of efficiency) generally showing a difference of approximately 20% lower emissions when compared to farm suckler systems operating at national average levels of efficiency in Ireland. This benefit, paired with the economic impact, was considered by the authors to illustrate the dual benefits of increasing efficiency in suckler beef systems.

5. Where does it work?

A target of calving at 24 months works best in farming systems that have good quality pasture available to support early heifer growth and maturity. Where forage is of lower nutritional value, such as on hill farm systems, reduced age at first calving remains an ideal, as it is unlikely that the age can be reduced as low as 24 months. However, reducing age at first calving by a few months can still improve the overall productivity of the system. As Diskin and Kenny (2016) illustrate, the calf is the primary output of the beef enterprise and, as such, reproductive efficiency is a fundamental component of on-farm profitability, regardless of the type of production system in question.

6. How much does it cost?

While the cost savings of achieving the target of 24 months of age at first calving are well documented in the literature, there are also costs associated with achieving this. The cost of applying this practice will vary depending on factors such as the production system, the type of breeding programme in place, the degree to which producers choose to make use of decision support tools, and the various management practices that are already in place on a farm. For example, the breeding season is a labour-intensive period that requires a high level of time spent monitoring the herd to achieve high levels of heat detection, followed by time spent handling animals daily when carrying out artificial insemination (AI). Handling costs are increased when heifers are brought in to be weighed to ensure target weights are met in the run up to breeding, along with infrastructural costs of handling facilities and weighing scales. There are various heat detection aids available to farmers at a range of price points, as well as genomics services that can support genetic improvement of the herd, and various nutrient supplements that help maintain a steady plane of nutrition in preparation for breeding.

7. How can the practice be done well?

This practice can be considered as the outcome of several components, including the timing of puberty and onset of ovarian activity, nutrition, health, and body condition score. These components are all influenced by the various management practices employed on-farm. The degree to which this practice is done well can be measured as the mean age of first calving on a given farm and the proximity of this figure to the target of 24 months of age.

Along with the core management practices that producers use on-farm to ensure the nutritional and health needs of the replacement heifer are being met, there are tools that can aid producers to achieve the higher level of animal performance required to do this practice well. Two examples of such support tools include genomic selection and a target-driven heifer growth management plan.

Crosson *et al.* (2016) illustrate the objective of maximising animal performance as producing one calf per cow per year. They proceed to outline that introducing practices such as genomic selection to the management approach on-farm allows for the identification of the most productive and fertile heifers from a very young age. This equips farmers with knowledge and data, which in turn allows for informed breeding decisions, supporting farmers to deliver on the genetic aspects that contribute to early onset of puberty.

In promoting calving at 24 months of age, a study conducted by Titterington *et al.* (2015) analysed farmers' experiences of using a decision support tool that automatically selects an age-specific target weight for heifers and specifies the daily live weight gain required to achieve the target within a three month time period. They found that the mean age at first calving was reduced by an average of 3.74 months across all six farms in the study as a result of applying the growth management plan. Having target weights for individual animals supports farmers in maintaining an adequate plane of nutrition up to time of breeding, and to identify and pre-empt any animals that may require greater attention to ensure they stay on track. Decision support tools such as this can support farmers to manage nutrition well and ultimately maximise the early onset of puberty observed across the replacement heifers in the herd.

In order to conduct this practice well, key management protocols must be adhered to by producers in order to ensure that heifers reach a number of key physical milestones in order to calve at optimum body size and body condition (Titterington *et al.*, 2015).

8. How strong is the evidence?

Several studies were identified that analysed the reproductive performance of suckler beef production, with varying degrees of focus on the impact of age at first calving. There is strong evidence from the literature to suggest that a mean age of 24 months old at first calving, as opposed to 36 months old or more, has clear benefits in relation to the lifetime production of a cow, the number and total weight of calves weaned, and ultimately the profitability of the suckler beef enterprise. The age at first calving of 24 months for heifers is frequently cited as a key reproductive target for producers to aim for, among others.

9. Where can I find further information?

- Further information can be found in a Teagasc article produced by Crosson *et al.* (2016), which outlines how profitability can be improved on-farm, including detail on maximising animal performance.

Technical discussion

There is adequate evidence within the literature examined to state that heifers that are calved at 24 months of age produce more calves and wean more weight of calf over the course of their productive lifespan, as compared to heifers that calve later. The evidence base has also demonstrated increases in profit as well as reductions in production costs, such as heifer feeding. In the same way that some other practices result in efficiency gains, so too this practice contributes to greater productivity, which has positive implications for on-farm environmental sustainability.

By managing the suckler beef operation in such a way as to reduce the mean age at first calving within the herd to 24 months, producers can enjoy the various benefits that achieving this target has to offer. However, achieving this target, and thus a high level of reproductive efficiency, requires a high level of management and technical competency. A key area of focus is the early onset of puberty in replacement heifers. In achieving first calving at two years of age, Diskin and Kenny (2014) underscore the early onset of puberty as an imperative component, being a consequence of genetics and both pre- and post-weaning nutrition all interacting with one another.

The key recommendations for this practice are:

- For farmers to incorporate calving of heifers at 24 months of age as a KPI within their business.
- Levy bodies could also continue to promote the well-established benefits that this management practice has to offer.

5.2.2. Score cow condition and adjust diet accordingly

Narrative summary

Body condition scoring (BCS) is a method of using visual and/or tactile measurements to estimate body fat and condition of suckler cows. Cows are scored on a scale of 1 (emaciated) to 9 (obese), with a score of 5-7 at calving being ideal. Table 16 presents the benefits of calving cows at the ideal BCS compared to either too high (marked with an asterisk) or too low.

Table 16. Impact of scoring cow body condition and adjusting diet accordingly on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1. Scores in brackets show potential indirect impacts as a result of increased production enabling a reduction in the replacement rate, although these scores were not quantified in the literature.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
++	+	+*	+	NA	+*	(+)	(+)	NA	(+)	NA

Evidence base			**Cost to implement**	££
Quality	●●●○○		**Time to implement**	Fast
Relevance	●●●○○		**Time to impact**	Moderate
Overall	●●●○○		**Suitable systems**	Mainly intensive

* Presents the benefits of calving cows at the ideal BCS compared to too high.

1. What is the practice?

Body condition scoring (BCS) is a simple method of determining the condition of livestock. It uses visual and tactile measurements, coupled with a reference chart, to assign a score to each animal. There are different scoring systems that can be used for this. The 5-point scale and the 9-point scale are examples of the most common BCS systems in use. In this narrative summary, the 9-point scale has been used as an indicative system as it was the most used scale within the evidence base examined. This scale scores animals between 1 (emaciated) and 9 (obese). There is a large body of evidence supporting the benefits of calving cows at BCS 5-7, since too low means cows are less able to recover energy reserves after rearing a calf which reduces subsequent fertility, while too high increases the risk of calving difficulty and feed intake (Eversole *et al.*, 2009). Eversole *et al.* also highlight that an optimum BCS is aligned with good milk production and calf vigour, as well as fewer health issues. BCS is primarily determined by nutrition and is an important indicator of a cow's subcutaneous fat reserves, a key energy source post-calving.

2. How effective is the practice at improving productivity?

After calving, cows go through a period of post-calving anoestrous, where they do not undergo oestrous cycles to give time for the uterus to return to pre-calving size. BCS score at calving is a major determinant of the duration of post-calving anoestrous and is determined by energy and protein intake during pregnancy. Insufficient nutrition pre-calving (as reflected in BCS scores at calving) increases the proportion of time cows spend in anoestrous during the breeding period, which increases the calving interval (Montiel and Ahuja, 2005). Pre-calving nutrition is more important than post-calving nutrition in determining the length of post-calving anoestrous with a negative correlation between BCS score and duration of post-calving anoestrous (Montiel and Ahuja, 2005).

BCS score at calving is likely the single most important factor linked to the timely resumption of fertile ovulation post-calving (D'Occhio, Baruselli and Campanile, 2019). A summary of eight trials with over 1000 beef cows showed that cows with a BCS of 4 or lower, 5, or 6 or higher at calving had pregnancy rates of 61%, 79% and 90%, respectively. In a study by Montgomery, Scott and Hudson (1985), as cited by Montiel and Ahuja (2005), Angus cows fed a higher energy ration for 55 days before and 40 days after calving had 35 kg greater liveweight and a shorter interval from calving to first oestrous than cows fed on a medium nutrition ration. Cows with relatively good BCS at calving also tend to wean heavier and healthier calves and this has important implications for young heifers destined to become breeders (D'Occhio, Baruselli and Campanile, 2019).

DeRouen *et al.* (1994) suggested that BCS at the time of calving is likely the most important factor affecting subsequent net calf-crop in mature beef cows. They found no difference between cows that maintained sufficient BCS throughout pregnancy and those that were fed a high energy ration to increase BCS within the last trimester suggesting an opportunity for management strategies to increase BCS in the few months prior to calving.

Cows that calve with a BCS of 8 or above were found in two papers to increase the risk of calving difficulty, although no quantification was provided.

3. How effective is the practice at improving profitability?

Only one study in the US directly investigated the economic benefits of calving at optimal BCS (Eversole *et al.*, 2009). They reported that income per calf increased from $359 for calves from cows at BCS 3 to $416 for calves from cows at BCS 5 (16% increase). This is likely due to increased weaning weights, shorter calving intervals and reduced culling, although no detail was provided. Ensuring cows do not reach excessively high BCS scores is also important since they have greater feed requirements.

4. How effective is the practice at improving environmental sustainability?

No papers were identified that directly investigated the environmental impacts of calving at optimal BCS, however reducing the calving interval, improving the percentage of cows in calve and reducing the number of culls due to late conception will all support a reduction in herd GHG emissions. Preventing excessive BCS will have indirect benefits by reducing the quantity of feed required (particularly grains), with reductions in GHG emissions associated with these. There may also be indirect benefits for water quality where feed is reduced and there is therefore less nitrogen excreted.

5. Where does it work?

Body condition scoring is most practical in production systems where there is sufficient infrastructure to bring cows inside and score throughout pregnancy to monitor changes in BCS and take appropriate management decisions to address issues.

6. How much does it cost?

There are no direct costs involved in body condition scoring; however, it requires additional time and labour, which would be dependent on the number of cows being scored and the type of handling system implemented.

7. How can the practice be done well?

Eversole *et al.* (2009) provide guidance on best practice for BCS. They suggest that body condition should be evaluated and recorded at weaning (for heifers), 60-90 days before calving, and at calving. Evaluating BCS at weaning allows heifers to be separated into groups with different feeding regimes to ensure that as many animals as possible can reach BCS 5-7 by calving. It is economically optimal to only provide higher nutrition to the animals that need it, such as by providing access to supplemental feed and/or higher quality grass. Where supplements are used, it is best to provide a small supplement over a longer period to gradually build condition, since high levels of supplements reduce forage intake and digestibility. Scoring heifers and cows 60-90 days before calving can identify animals that are not on track to reach that target, which can then be separated and given a more energy-intensive ration if needed to increase the BCS in the last trimester of pregnancy.

8. How strong is the evidence?

There is broad consensus within the evidence base that calving at BCS 5-7 is optimal and improves cow fertility and calf performance. Five papers were identified that discussed the productivity impacts, of which two were reviews. However, much of the data quoted was produced in older studies, often in the USA, and there were no recent studies in the UK context identified. Nonetheless, the evidence base is sufficiently consistent and robust as to recommend calving cows with a BCS of 5-7 for optimal herd performance.

9. Where can I find further information?

- Defra produced an information booklet called Condition Scoring of Beef Suckler Cows and Heifers which provides a visual guide to BCS.
- Virginia Tech produced an article describing the background to BCS, some of the benefits, and a visual assessment guide with whole-animal photographs. (Note: US-focused).

Technical discussion

There are clear benefits for farmers to monitoring BCS scores of suckler cows and managing them to ensure they calve at the optimum score. It was not clear from the literature how widespread this practice is on UK suckler beef farms. A survey to understand existing practice would be beneficial to direct future interventions. This survey should capture information on herd size, production system, whether BCS is done and if so, how often, as well as knowledge of BCS scoring including the optimal scores for calving, and the problems associated with calving at a BCS which is too high or too low.

Additionally, while some high-level recommendations are provided here on how to manage cows to achieve the optimal BCS at calving (e.g. separating thin cows to manage differently), there is scope for more practical guidance in the UK context, potentially communicated through breed associations, veterinarians or levy body knowledge exchange.

The key recommendations for this practice are:

- For industry bodies to strengthen the evidence base in this area to facilitate creation of UK-specific guidance.
- It is recommended that farmers incorporate this practice where applicable within their enterprise and make use of practical guidance made available by levy bodies.

5.2.3. Conduct a pre-breeding examination on stock bulls

Narrative summary

Pre-breeding examinations are a method of checking the fertility of stock bulls prior to breeding. They involve visual assessments, measurements and sperm analysis to identify poor or absent fertility, ensuring the maximum number of cows are successfully serviced within the desired interval. Table 17 describes the impact of using pre-breeding examinations to ensure that sub-fertile bulls are not used for breeding.

Table 17. Impact of conducting pre-breeding examinations on stock bulls on productivity, profitability and environment, including an assessment of the cost and time to implement and relevance to different production systems. All impacts assessed in line with the Evidence for farming – evidence standards as set out in section 4.2.1. Scores in brackets show potential indirect impacts as a result of increased production enabling a reduction in the replacement rate, although these scores were not quantified in the literature.

Practice impact on:										
Productivity				**Profitability**		**Environment**				
No. calves	Weaned weight	Calving difficulty	Cow weight	Added value	Reduced cost	Air	Water	Soil	Climate	Biodiv.
++	+	NA	NA	NA	NA	(+)	(+)	NA	(+)	NA

Evidence base			**Cost to implement**	££
Quality	●●●○○		**Time to implement**	Fast
Relevance	●●●○○		**Time to impact**	Moderate
Overall	●●●○○		**Suitable systems**	All

1. What is the practice?

While much attention is given to improving the fertility of females in the herd, there is comparatively little focus on male fertility. However, given that each bull will service 30-40 cows, it is important to ensure that this is well managed. One method of ensuring good bull fertility is the use of pre-breeding examinations (also known as breeding soundness evaluations) on stock bulls. This involves a visual assessment of the animal, scrotal measurements and often includes a sperm motility analysis. These evaluations can detect infertile or sub-fertile bulls, preventing their use as stock bulls and maximising the number of cows in calf within the desired timeframe.

2. How effective is the practice at improving productivity?

There was broad consensus across the evidence base that a substantial proportion of stock bulls are sub-fertile. One study, by Walters and Thomson (2011), found that 29% of UK bulls in a study of

339 evaluations failed either the visual assessment, sperm assessment or both. Of bulls that had produced unsatisfactory pregnancy rates, 82% of them also failed the examination. This is aligned to other research, including a review by Barth (2018) that found that 20% of bulls were defective in some way, with 25% of bulls having impaired serving capacity.

While no direct quantification was identified, these data would suggest that a lack of routine pre-breeding examinations is likely to result in reduced herd fertility, with fewer cows in calf within the desired timeframe.

One study by Kastelic (2014) looked at one aspect of breeding soundness – scrotal circumference – to infer fertility of bulls. They found that bulls with scrotal circumferences of more than 34 cm had a significantly higher percentage of normal sperm than bulls with a circumference of 34 cm or less. Cows exposed to bulls with smaller scrotal circumference were significantly less likely to be diagnosed pregnant and had a significantly longer median interval between first exposure to the bull and calving compared to those exposed to bulls with larger scrotal circumferences.

Barth (2018) also estimated that for every 21-day period of the breeding season that a cow fails to conceive, there is a loss of 23 to 27 kg of weaning weight the following year for the calf she finally conceives, providing some evidence that weaning weight is also affected by delayed conception.

3. How effective is the practice at improving profitability?

While no studies were identified that directly determined the economic impact of poor bull fertility, it is widely known that maintaining a tight calving block is critical to ensure productivity and profitability of suckler cow operations. Using sub-fertile bulls results in fewer cows in calf and/or cows conceiving late, which reduces output and may force sale or culling of animals unnecessarily. Barth (2018) also estimated a direct reduction in weaning weight as a result of delayed conception, which will have additional impacts on income per calf. Therefore, using bull pre-breeding examinations can prevent the use of low fertility bulls and improve herd productivity and profitability.

4. How effective is the practice at improving environmental sustainability?

No studies were identified that explored the environmental impact of bull pre-breeding examinations. However, since this practice improves herd productivity, there will be indirect benefits. Minimising the number of barren cows will reduce GHG emissions, ammonia emissions and nitrate leaching per unit of output, since productivity is maximised.

5. Where does it work?

Bull pre-breeding examinations can be done in any system with access to handling facilities, provided there are locally available veterinarians with the expertise and equipment necessary to carry out the examination.

6. How much does it cost?

A full bull pre-breeding examination, including sperm motility analysis, is likely to cost in the region of £100 exc. VAT (*Damory Vets*, no date). Farmers can observe mating to determine whether or not bulls are actually servicing cows as a means of incorporating a low-cost screening method to mitigate the risk of having low-fertility bulls on farm (Barth, 2018).

7. How can the practice be done well?

To maximise the effectiveness of pre-breeding examinations, it is important to get the timing right. The examination should be conducted close enough to breeding that the bull's condition will not change before being put out with cows but still allowing enough time to arrange a replacement if fertility is found to be sub-optimal, with around two months being the optimal time (*Damory Vets*, no date).

8. How strong is the evidence?

There is a robust body of evidence supporting the fact that a substantial percentage of stock bulls in the UK are sub-fertile, with figures ranging from 20-30%. In one study (Walters and Thomson, 2011), bulls that produced poor conception rates were tested using a breeding soundness evaluation, with 82% of them failing. This suggests that pre-breeding evaluations will not guarantee breeding success, but it is likely to detect the majority of issues that result in sub-optimal bull fertility.

9. Where can I find further information?

- Teagasc provide a short bulletin introducing bull pre-breeding examinations, outlining the key benefits.
- Teagasc provide a comprehensive guide to all aspects of pre-breeding examinations, with detailed information, visual guides and recommendations of best practice.

Technical discussion

Bull fertility is affected by several factors, some of which are under the control of the farmer. By ensuring proper management, fertility can be maximised. Barth (2018) lists the main factors as:

- Age

- BCS
- Physical abnormalities
- Scrotal circumference
- Season
- Nutrition
- Management

Bull fertility can be maximised by replacing older bulls, managing body condition through optimal nutrition, and addressing health concerns. Pre-breeding examinations are particularly important when purchasing new bulls or when there are any concerns about a bull's fertility.

The recommendations for this practice are:

- For farmers to conduct pre-breeding examinations at the appropriate times during the year for their individual farm systems.
- It is important for industry bodies to continue to place emphasis on the relevance of this practice and the implications that an infertile bull can have on productivity and profitability.

6. Practices requiring further research

This section presents summaries and future recommendations for practices where there was insufficient evidence to determine what the impact of the practice was on productivity, profitability and/or environmental sustainability. Some of the practices below had a substantial volume of discussion within the literature, with several of them even being the subject of comprehensive reviews. There is often anecdotal evidence, opinions or perceived general knowledge on the direction of impact, however in all cases there was an absence of robust evidence and no indication of the scale of impact. The summaries below present the practice, provide information on where it may be applicable and the potential direction of impact, as well as any specific gaps in the evidence base. The recommendations part of each practice describes specific steps that could be taken to address these gaps and provide robust data in order to support farmer decision making.

6.1. Genetics and breeding

6.1.1. Use a maternal selection index

Summary

While the main focus of genetic selection within suckler beef herds is sire genetics, there is also an opportunity to improve genetic selection of female animals. This can be achieved in two ways; using selection indices to identify suckler female replacements with improved maternal traits or identifying sires with the genetics for breeding high profit replacement females.

This practice explored using selection indices to select females with improved maternal traits, such as calving ease and milk yield. First, these traits need to be quantified, either directly, such as by monitoring observed rate of calving difficulty, or indirectly, such as using pelvic measurements to infer the likelihood of calving difficulty. Collecting data on these traits can have increased labour implications on-farm. In addition, accuracy for younger animals is dependent on multiple years' worth of data. While there was some discussion within the literature of selecting sires with superior genetic merit for maternal traits for use in breeding replacements (e.g. using the ICBF Irish Maternal Replacement Index), there was very little information within the evidence base to enable an evaluation of the impact of directly selecting females using a selection index including these traits. However, given the variability of these traits within the population and the fact that they are at least partially heritable, it is likely that selecting females with superior traits will lead to improvements in herd productivity and profitability (McCabe, McHugh, *et al.*, 2019). It is important to note that genetic evaluations, while a powerful tool in determining the genetic potential of animals, are just part of their actual performance. A heifer that is genetically superior may not actually deliver the improved performance if the environment is not sufficient to enable these traits to be expressed. Therefore, heifer nutrition and management are also key in ensuring that the benefits of improved genetics are realised (D'Occhio, Baruselli and Campanile, 2019).

Recommendations

One of the main barriers to female genetic selection is the time and labour cost of assessing the relevant traits. More evidence is needed to demonstrate the value of female genetic selection, which places greater labour burden on the farmer than sire selection.

Genomics presents a substantial opportunity to improve the practicality of this practice on-farm. If DNA samples were collected from all heifer calves at birth, and genomics could be used to accurately determine their genetic potential, then this would make selection of superior females more robust, before they even enter the breeding herd. Similarly, this would allow for the selection of sires to cross with breeding females before they have daughters with measurements, advancing the pace at which genetic gains can be made within the herd.

The key recommendations for this practice are:

- For farmers to incorporate the use of a maternal index as part of their breeding management plan.
- To encourage greater uptake of this practice, further evidence is required to demonstrate the value in doing so and levy bodies could conduct further research to deliver on this.

6.1.2. Breed for improved calving ease

Summary

Calving difficulty is a major issue in many suckler beef herds, particularly in pure bred continental breeds. One study, by Bragg *et al.* (2021) estimates that 20% of calves born in UK suckler beef herds require assistance. This is likely an underestimate since this study did not include caesarean sections or calves that were born dead. Calving difficulty can result in a range of complications that reduce the productivity of the herd, including increased risk of injury or death for both the cow and the calf, reduced intake of colostrum (which reduces immunity to pathogens) and increased time, labour and veterinary costs. Calving difficulty is partially heritable, therefore selecting cows with reduced risk of calving difficulty to breed replacements, coupled with selecting sires who produce daughters with reduced risk, should reduce incidences of calving difficulty. The literature search revealed several good reviews of calving ease (Hickson *et al.*, 2007; Zaborski *et al.*, 2009; Hohnholz *et al.*, 2019; Bennett *et al.*, 2021; Bragg *et al.*, 2021), including the consequences and risk factors, although little evidence was found to quantify the potential impact that selective breeding can play in reducing incidence of calving difficulty. Calving difficulty can have a severe impact on the productivity of individual cows and where incidence rates are high this can substantially affect herd productivity and profitability. A study by Holmøy *et al.* (2017), looked at lifetime productivity data from 20,541 cows in 2,210 herds in Norway over a three-year period. They found that moderate calving difficulty at first calving reduced lifetime calf production by 13%, while severe calving difficulty at first calving reduced lifetime calf production by 30%. A study by Hickson *et al.* (2007), in New Zealand found that the main cause of calving difficulty is the birth weight of the calf, followed by the cow's maternal traits such as pelvic dimensions. The challenge is that there is a trade-off between calving difficulty and terminal traits (there is an association between birth weight and growth rate). Novel fertility approaches such as sexed semen could be used to ensure that heifers and cows at risk of calving difficulty produce small (female) calves.

Recommendations

There was a large volume of information in the literature discussing calving difficulty, particularly the risk factors and impacts. However, there was very little quantitative evidence to translate this information into losses in productivity on-farm. One report found that suckler calf mortality in the first 21 days of life was 4.4% in the UK (AHDB, 2020). Quantifying the impacts of productivity losses is an important step to be able to illustrate the impact of calving difficulty in terms of profitability, which would justify increased prioritisation of this trait as a breeding goal.

Calving ease is a multi-faceted issue, and more research is needed to understand the dynamics between breed choice, calf genetics (e.g. sire selection), maternal traits (such as pelvimetry) and maternal nutrition during pregnancy, as indicated by BCS.

The recommendations for this practice are:

- For farmers to continue selecting for improved calving ease.
- For levy bodies to continue work in this area, particularly in generating data to quantify the impact that difficult calving has on productivity within the suckler beef enterprise, which will in turn reinforce farmer decisions to make this a key priority on-farm.

6.1.3. Use genomic techniques

Summary

Conventional genetic selection relies on estimated breeding values (EBVs) – measures of the expected difference in a trait between a genetically superior animal and an average animal. E.g. if a bull has an EBV of +10 kg 200-day weight, it would be expected that this bull would be 10 kg heavier than the average at 200 days. Half of this improvement would be passed onto the bull's progeny (*BREEDPLAN*, no date). Genomics uses an animal's DNA to predict genomic estimated breed values (GEBVs), rather than relying solely on recorded pedigree and actual measurements of the traits, which has a number of advantages, particularly for traits that are difficult to measure. GEBVs can be determined at birth, so breeding decisions can be made without having to wait until the traits are expressed, which reduces generation intervals and results in more rapid rates of genetic gain (Wickham *et al.*, 2012). While genomics is widespread within the dairy sector, no papers were identified that quantified the impact of genomic selection within the suckler beef sector.

Genomics has substantial potential to improve productivity of suckler beef farms, but the sector has been slow to implement the technology. While any bull or cow could be genotyped, it is not standard practice and so breeding animals tend to be selected based on the parent average of EBVs if they are available, or on observed phenotype rather than genetic potential. A key difference in the use of a parent average compared to a GEBV is that the GEBV will allow for more confident selection decisions at an earlier stage as a result of greater accuracy compared to parent average. The extensive use of AI in the dairy sector means it was already poised to add genomic assessments on to the existing bulls, enabling farmers to make decisions without waiting until the bull was mature and his daughters had entered the milking herd. The relative lack of AI, particularly on large suckler beef farms (Telford, Beard and Franks, 2003), restricts the application of genomics.

Recommendations

The most obvious application of genomics within the suckler beef sector is within the AI market. With AI, comparatively few bulls serve a large number of cows and so the costs of genomic analysis are diluted. Additionally, there are large cost-savings to be made by genetics companies in determining the genetic potential of animals early in life to minimise investment costs on animals that are unlikely to deliver superior genetics. This is already the case in the dairy sector, where there are a large number of young bulls available that are unproven and only their GEBVs are published.

On-farm genomic analysis, both of stock bulls and of female cows, would require DNA being sampled on-farm and genomic analysis being performed to identify the most genetically superior animals for breeding replacements. It is also worth noting the importance of maintaining a robust phenotyping strategy in order for genomics to remain effective. The accuracy of GEBVs decreases as the number of generations between reference bulls and candidates increases, which requires new bulls to be introduced into the reference population over time to counteract this effect and recalibrate the genomic data with real measured phenotypes. For genomics to be successful, more work is needed to demonstrate the benefits of genomic selection over a period of time, compared to conventional selection based on phenotype.

The recommendations for this practice are:

- Encourage the use of genomic techniques by farmers, for the confidence and accuracy gains related to breeding decision-making, as well as genetics companies, for the potential cost-savings in determining the genetic potential of animals, which can inform investment decisions.
- Levy bodies could also continue to play a role in promoting the benefits of using genomics and what the suckler beef sector has to gain.

6.2. Calving and fertility

6.2.1. Regularly weigh breeding heifers to ensure optimal growth rates

Summary

Heifer management is important in setting up future lifetime productivity and fertility. Ensuring they have adequate nutrition to achieve optimal growth rates will enable earlier age at first calving and support good fertility (D'Occhio, Baruselli and Campanile, 2019). Regularly weighing heifers enables farmers to determine whether they are on track to reach the required weight at service, in order to achieve optimal age at first calving (Pulina *et al.*, 2021). If sub-optimal growth rates are detected, this enables the ration to be adjusted in order to meet these growth targets. Although regularly weighing heifers is broadly viewed as best practice, no papers were identified that quantify the productivity impacts of carrying out the practice. Correct nutrition is essential for optimal productivity and is expressed through weight and body condition. Regularly weighing and scoring body condition is a useful way to objectively measure whether the ration is meeting the animal's requirements (DeRouen *et al.*, 1994). There is a range of options when it comes to weighing, from simple scales to advanced handling systems with automatic recording and linking with cattle ID numbers. Regularly weighing heifers is challenging to implement in many farms due to the requirement for handling facilities and increased labour requirements. Additionally, weighing on its own does not

improve productivity – it simply provides information about which heifers are underperforming. It is then up to the farmer to adjust the nutrition regime accordingly, which may not be possible due to the constraints of the production system.

Recommendations

Given the relatively high labour and infrastructure costs associated with regularly weighing cattle, even for systems where handling facilities are already present, more information is needed to determine if these costs are justified by improved productivity. While sufficient weight at service is necessary to ensure optimal age at first calving and maintain the block calving cycle, it is unclear whether regularly weighing heifers is a reliable and consistent way to ensure that this happens. Further information is also required on the optimal frequency of weighing, bearing in mind the high labour cost each time the practice is done. Weighing at birth and at weaning are sensible opportunities where heifers may be housed anyway, reducing the labour burden, but it remains unclear whether this is sufficient to deliver the results required.

Additionally, weighing on its own does not actually ensure correct weight at service. It is the actions taken in light of this information, such as splitting the herd into groups with separate rations, that can help to ensure weight at service. This information can also enable farmers to identify health issues perhaps earlier than otherwise might have occurred, as well as providing farmers with accurate animal weights with which they can use to ensure medicine dose rates are correct. Clear, practical, farmer-facing guidance is needed to help translate information on growth rates into actions that ensure optimal weight at service.

The recommendations for this practice are:

- For farmers to incorporate weighing of animals into their heifer rearing management plans.
- It is also recommended that levy bodies establish a robust knowledge base that informs farmers as to what options are available to them and might be most applicable to their individual farm setups, as well as general guidance (e.g. optimal frequency) around weighing to ensure farmers yield the greatest potential from labour inputs related to data collection.

6.2.2. Tighten block calving window

Summary

Calving cows in blocks as opposed to all year round calving or even an extended calving period is expected to contribute to the productivity of the suckler herd, as well as lowering costs of labour and feed. The practice of tightening the block calving window aims to maximise these efficiency gains by minimising the amount of time that extra labour is required on-farm. By tightening the block calving window, the number of days spent at grass can be maximised as well as turnout to grass aligned with the peak grass growth period. Maximising utilisation of grass in the diet has been demonstrated to reduce costs. Spring calving herds, as compared to all year round calving herds for example, have been shown to have a lower mean total cost of rearing from weaning to conception, by as much as £300 per heifer reared (Boulton, Rushton and Wathes, 2015). The literature that was examined that engaged directly with the practice of tightening the block calving window demonstrated clear benefits in relation to productivity and profitability. These benefits were most notable in the case of reduced labour over the course of a year, with more concentrated labour during calving periods. As Diskin and Kenny (2016) illustrate, maximising the number of cows that get in calf within the first 42 days of the breeding period helps tackle the issues that may arise as a result of later calving cows within the herd. Such issues include extended postpartum anoestrous interval, which can lead to extended duration of calving as a result of a disrupted calving pattern. As discussed above, this can contribute to increased costs of production and decreased productive efficiency on-farm.

Recommendations

While there has been reference to the cost benefits associated with having a tighter calving block window as one component compared amongst various different production systems within the literature, there has not been substantial work done to quantify the impact of this management practice specifically in the context of suckler beef and, as such, limited the extent to which strong conclusions could be formulated. Although the currently available evidence shows where gains can be made, further investigation in this area would provide producers with a more robust, context-specific knowledge base from which they can draw the necessary information to inform decisions on their own farms.

The recommendations for this practice are:

- For farmers to prioritise tightening the block calving window as a KPI within their business.
- For levy bodies to promote further investigation to address the current knowledge gap, quantifying the benefits in greater detail to underscore the value that this practice can deliver for suckler beef producers.

6.3. Feed

6.3.1. Match nutrition to animal requirements

Summary

Ensuring that cows have adequate nutrition is essential to maintain optimal body condition at calving, maximise fertility and health, and to produce adequate volumes of milk to ensure optimal calf growth (D'Occhio, Baruselli and Campanile, 2019). To achieve adequate nutrition, farmers have to know what the nutritional content of the ration is and also what the nutritional requirements of the stock are. Forage makes up the majority of the suckler cow ration, therefore, it is advised to test the nutritional quality of grass and silage, in terms of dry matter, energy, fibre and protein content. Where the quality is sub-optimal, this can be compensated for through addition of high energy or high protein feeds. Understanding cattle requirements is more challenging, since it varies widely depending on the breed, production system and reproductive status of the animal. Regular weighing and body condition scoring are useful indicators of nutritional status. There are also a range of tools available to estimate feed requirements, from simple lookup charts to more detailed software packages.

Recommendations

Clear, practical guidance on the nutritional requirements of different breeds and classes of livestock, backed by evidence-based research would provide a starting point for farmers to determine the correct nutrition for their animals. This should be coupled with guidance on typical nutritional content of different feeds, how to incorporate information on silage quality and how to calculate optimal rations. This material should be supplemented with guidance on how to use BCS and weight gain measurements to verify that nutrition is adequate and how to respond where it is not.

The recommendations for this practice are:

- For levy bodies to enhance the evidence base and generate material to communicate how producers can best achieve this practice for their individual systems and beef breeds.

6.3.2. Use an alternative grazing pattern (mob/rotational versus set stocking)

Summary

Conventional grazing patterns typically involve keeping livestock at a relatively low density for an extended period of time. In contrast, alternative grazing patterns, also referred to as mob grazing, paddock grazing or rotational grazing, see animals stocked at much higher density, but for a much shorter time – sometimes as little as one day – before being moved onto the next area while the previously grazed area is given extensive time to recover (Teague *et al.*, 2013). Alternative grazing patterns have been promoted as a way to improve animal productivity, forage growth rates, soil health and carbon sequestration; however, these claims are not fully supported by the scientific literature. An REA of mob grazing is currently being conducted by ADAS as part of a Defra-funded project led by ADAS (ADAS, no date); the initial data search has found only limited data on the impacts of mob grazing, with very little regarding a UK context. There was no evidence for consistent impacts on productivity – either for the grassland or animals – under mob grazing patterns. In terms of GHG emissions from fields and the potential of soil carbon sequestration, results were variable, with few significant differences found between mob grazing and rotational or conventional grazing. One of the challenges in assessing the impact of mob grazing is the lack of standardisation within the practice in terms of stocking density or grazing duration, with a range of similar systems all described by synonymous terms. Mob grazing requires some additional infrastructure and labour to manage successfully, typically permanent or temporary electric fencing of small paddocks or the use of geo-fencing collars.

Recommendations

One of the challenges facing alternative grazing systems is the wide range of different terms for several similar systems, with no standardisation of stocking density or duration. While this REA yielded no papers that quantified the benefit on productivity, there are studies, both from the UK and abroad, that have explored alternative grazing systems. A useful first step would be to collate this information and harmonise some definitions of what the different systems are. Clearly defining what the different terms mean in terms of a range of stocking densities and grazing durations would at least allow comparison of similar studies, although it is expected that there is considerable overlap between terms within the existing literature.

After defining the terms, future work should address the impacts of alternative grazing systems on a range of parameters, with a consistent approach taken between different farms to determine differences between soil types and climates. A Defra-funded project led by ADAS will build on the mob grazing REA with field work to address this.

Of course, it is important to state that regardless of the specific grazing pattern used, grassland management to improve productivity is important. This includes optimising nutrition and liming where necessary.

The recommendations for this practice are:

- For levy bodies to conduct work in this area and establish a standardised approach to grassland management in the context of suckler beef production. This work is ongoing, and industry is collating data to better understand the impacts that alternative grazing systems can have on productivity.

6.4. Management

6.4.1. Appropriately timed culling

Summary

The purpose of culling in the suckler beef enterprise is to replace generally older, less productive cows, that may also be of poor health, with young replacements of higher genetic merit and improved fertility, that will ideally increase the productivity of the herd. Another scenario in which cows may be culled is that of empty cows that failed to go in calf. The point in the dam's life cycle at which culling is most optimal will depend on the market in which a given suckler beef system operates.

In determining the appropriate time to cull, two interconnected factors for consideration include: biological efficiency, which considers the number of calves weaned per cow and the weights of calves produced, as well as economic efficiency, which considers the longevity of cows in the herd and how the costs of rearing the cow are spread over the number of calves produced.

The literature indicates that it is beneficial to determine the appropriate time to cull animals in terms of productivity and, thus, profitability. It was clear from the evidence examined that the optimal time for culling is dependent on the market in which the suckler beef system operates, the relative value that is placed on calves and dams, as well as the constraints that producers may face, such as land area or the ability to increase intensity per unit of land. There was insufficient evidence within the literature to build a clear picture of appropriately timed culling in the UK, with the sources examined originating from North and South America. However, the principles identified in determining the optimal time to cull animals from the herd are still widely applicable in the UK and can inform best practice in the area of productive efficiency.

A Canadian study (Naazie, Makarechian and Hudson, 1997) found that, through the development of a beef efficiency model, increasing dam maturity by 10% gave rise to a large decline in productive efficiency across the herd (as much as 35%, depending on breed).

Research conducted in Brazil (Sessim *et al.*, 2020) indicated by means of a simulation model the optimal age for culling in different production scenarios. The findings highlighted that culling cows at an older age resulted in greater economic efficiency per cow, even in the case of lower biological efficiency, whereas culling cows at a younger age resulted in greater bioeconomic efficiency per unit of land area. This led to the conclusion that culling cows at an older age is better suited to suckler beef enterprises where intensification of operations is unviable, whereas culling cows at a younger age was optimal in markets that place a greater value on culled cows and where intensification of cultivated pastures is an option. It is worth noting that, from an environmental sustainability perspective, culling cows at an older age allows for the emissions footprint of the cow (in particular, the emissions generated while the cow was being reared as a replacement heifer) to be divided over a greater number of calves, with each additional calf that the cow produces effectively dividing emissions. This highlights the impact that increasing reproductive efficiency can have and this will inform decision-making on-farm that relates to the optimum age to cull cows, particularly in the context of market demands and associated emissions reduction requirements.

Recommendations

Although there was varied discussion on the optimum time to cull cows in the literature examined, originating from different parts of North and South America, the available pool from which to draw information from was small, thus limiting the ability to evaluate this practice in a UK context. Further research and analysis of the optimum age to cull cows in various beef production scenarios would build on previous work and support producers in decision-making, providing them with access to an evidence base that has direct relevance to the UK.

The recommendations for this practice are:

- For levy bodies and industry to conduct further research to develop an up-to-date evidence base that is relevant to the UK context.
- Collating and analysing further data to better understand the impacts that this management practice has would provide farmers with the support to make confident decisions around culling of animals within their suckler herds.

7. Discussion

The aim of this review was to determine the impact of implementing various practices on the productivity, profitability and environmental sustainability of UK suckler beef farms. In total, 16 practices were reviewed, of which eight practices were found to have a sufficient evidence base to quantify the potential impact on one or more outcomes. For the other practices, while the impact was unknown, there was often substantial discussion around the practice, which may offer some insight into the direction of effect. This section discusses the implications of this work in addressing the productivity, profitability and environmental sustainability challenges facing the sector.

7.1. Productivity

Productivity is the main focus of this report, since it underpins many aspects of profitability and environmental sustainability. When conducting the REA, we therefore focused on search terms related to productivity. Productivity is defined in this report as the ratio of inputs to outputs. Within a suckler beef herd, the outputs are primarily the number and weight of weaned calves, as well as the weight and carcass quality of cull cows. Inputs are mainly labour, feed and other consumables.

Genetics and selective breeding approaches have been used to improve the productivity of crop and livestock system for thousands of years, with substantial progress made in the last few decades. The UK suckler beef sector is very diverse, covering a wide range of breeds, environments and production systems. There are purebred native breeds, like Angus and Hereford, which are faster to mature (and therefore can achieve a faster age at first calving) and produce smaller calves, reducing the risk of calving difficulty compared to continental breeds such as Charolais and Limousin, which produce larger calves with faster growth rates and heavier weights at weaning. Many suckler cows in the UK are the result of dairy-beef crosses, which are easier calving and produce greater milk yields (and therefore calf growth rates) than purebred animals. The choice of breed is the foundation of the herd's productivity and should be chosen based on the constraints of the production system. For example, upland farms with limited forage quality may be unable to support large continental breeds with high feed requirements, but will be able to extensively graze native breeds. Likewise, the intended market is important – continental crosses are sought after as suckler replacements, while some native breeds can be sold into premium markets.

Even within breeds, there is substantial genetic variation across both productivity and maternal traits. Productivity traits include calf growth rates, weaned weights and carcass quality, while maternal traits include calving ease and milk yield. There is often a trade-off between these, for example selection for productivity can result in increased calf birth weights, which is a key factor in calving difficulty. The use of selection indices could provide an opportunity to breed replacement heifers with a balanced mixture of productivity and maternal traits, which could be crossed with sires chosen using a terminal index to maximise the productivity characteristics of the resulting calves. With future uptake of artificial insemination and sexed semen in the beef sector, there is much more scope for rapid genetic gain and the ability to more precisely select for maternal traits in females and terminal traits in males.

Breeding for a reduced mature cow size to the point where the size of animal on-farm is closely aligned to the optimum size for a given suckler beef enterprise provides efficiency gains in the form of reduced feed and forage inputs. By reducing inputs while maintaining levels of output, there may be potential to go further and increase productive output, for example, by increasing stocking rates.

In the same vein, breeding for lower residual feed intake is potentially a "win-win" – a trait that reduces inputs (feed intake) without affecting outputs. The challenge is that accurate measurement requires costly and time-consuming feed intake recording, particularly at pasture, although this presents a substantial opportunity for genomic approaches, estimating the strength of a trait using DNA at birth, rather than waiting for the trait to be expressed and measuring it as the animal approaches maturity. With increased widespread employment of genetic selection, the prediction accuracy of this trait will also improve. Initially, this will require significant investment to collect data, but in the long-term, once robust datasets are available for genomic approaches to be used, the requirement for costly and logistically challenging feed intake recording will be reduced.

Beyond genetics, there are a range of management practices that can improve productivity, particularly around nutrition and fertility. The number of calves weaned by the herd is dependent on the number of cows that are in calf, the number that calve successfully, then the number of calves that survive to weaning. The weight of those calves is dependent on their genetics and their mother's genetics and nutrition.

Ensuring animals have the correct nutrition is essential as this underpins fertility and milk yield, which are key drivers of calf numbers and weaning weights, respectively. Body condition scoring is a useful way to determine if nutrition is adequate, and calving at the optimal body condition score is essential to ensure a quick return to fertility post-calving and minimise the risk of calving difficulty.

Heifer management is also important as this lays the foundation for future productivity. Regularly weighing heifers can help ensure that their nutrition is adequate to meet growth requirements for calving at a certain age. Calving at 24 months is achievable in some systems, depending on the breed, the availability of quality forage, as well as the climatic environment and is the optimal age at first calving to ensure a consistent calving interval and minimise culls. Where it is not physically achievable, aiming to bring the average age of first calving closer to 24 months allows for a greater number of calves to be weaned over the productive lifetime of the cow.

To ensure the maximum number of cows are in calf, it is also essential to manage stock bull fertility. Sub-fertility is relatively common in UK suckler herds, affecting between 20 and 30% of bulls. Conducting bull pre-breeding examinations can help identify problems in advance, avoiding the use of sub-fertile bulls and maximising the number of in-calf cows.

7.2. Profitability

Profitability is directly related to productivity – the more calves a herd produces, and the heavier those calves are, the greater the income. Likewise, by reducing inputs such as labour and feed, there will be associated cost savings. However, there are often trade-offs between different elements of the suckler beef system, which makes determining the overall impact challenging. For example, purebred beef cows were shown to have heavier cull carcass weights with better carcass conformation, but this came at a cost of increased risk of calving difficulty, which could negate any benefits from the increased value.

Often, it was difficult to quantify the productivity gains from implementing a practice because there may be a range of different levels of implementation, or the changes happen over a long time frame. For example, the costs and benefits of scoring cow condition and using this to manage nutrition depends on how often the cows are being scored, the skill of the stockperson, how the cows are managed in response to scoring, etc. Likewise, addressing breeding goals through the use of tools such as selection indices, breeding for specific traits, or using artificial insemination to accelerate the rate of genetic gain, we can be confident that productivity will improve over time, but by how much and how quickly will depend on the genetics of the existing herd, the sires chosen, and so on.

On the other hand, practices that have a direct, quantifiable influence on key productivity indicators (e.g. number of calves born, average weight at weaning, cull rate, length of calving interval, percentage of cows in calf) can be more easily translated into financial values through building a simple model. This is discussed more fully in section 7.4. For example, reducing the age at first calving with the aim of 24 months has been shown to have a direct link with increased profitability. Some practices also increased the cost per unit of production, e.g. by improving the carcass quality, and therefore value, of calves and cull cows.

Originally, it was hoped that we would be able to determine wider financial impacts of implementing these practices beyond just prices and costs, such as creating diversification opportunities, improving financial resilience, or positively affecting consumer perception. However, none of these parameters were able to be quantified from the literature. This could be due to the fact that papers were primarily selected based on productivity criteria, a limitation of the REA approach whereby the search must be restricted to fit within time constraints.

7.3. Environmental sustainability

Environmental sustainability is a key challenge facing the UK suckler beef sector, with pressure to reduce greenhouse gas (GHG) emissions, ammonia emissions and nitrate leaching, while improving soil health and on-farm biodiversity. While papers were chosen based on productivity outcomes, where environmental impacts were measured these were included in the analysis. However, there was very little data gathered on direct environmental impacts.

Some practices included quantification of methane emissions as an indirect result of improving herd productivity, e.g. by reducing the number of followers. This type of analysis would be well-suited to a modelling approach, where information is entered on the herd structure, KPIs, etc. and calculations determine the outputs of the system, including beef production, GHG emissions, nitrates, and income. Rerunning the model under a series of different scenarios, where different parameters are changed each time, would give a herd-level view of the impact of improving different aspects of productivity, which would then support the implementation of different practices to achieve those improvements.

The majority of GHG emissions on a suckler beef farm are a result of enteric methane production and nitrous oxide from dung and urine (manure), which are in turn driven by the number of animals and the time they are on-farm. Therefore, any practices that reduce the number of replacements required to maintain productivity, or reduce the time taken for calves to reach sale weight will reduce enteric methane emissions and manure emissions per unit of productivity. Reducing the time and number of stock on-farm also has an impact on other emissions sources, mainly direct manure emissions and indirect feed emissions.

There are GHG emissions associated with the growing, harvesting, processing and transporting of feedstuffs. Any practice that reduces feed consumption will therefore have an indirect impact on embedded feed emissions. Breeding for reduced cow size or residual feed intake will result in a reduction in the amount of feed required which will both directly and indirectly reduce associated

GHG emissions. Feed use also impacts nitrate leaching and ammonia emissions, particularly concerning high-nitrogen concentrate feeds. By reducing intake of these, there will be a reduction in the quantity of N excreted or applied on-farm, which will reduce the quantity that is volatilised as ammonia or leached as nitrates.

Few of the studies went as far as linking the productivity benefits achieved in the individual practices to the GHG impacts, however, it would be possible to retrospectively model the changes to determine the impact of different practices.

Biodiversity can also be indirectly affected by productivity. By increasing the amount of beef produced per area of land, this theoretically reduces the land required for beef production, assuming demand stays constant. This reduces the requirement to import beef into the UK from other countries, which is often linked to biodiversity loss and GHG emissions. Cattle are also used in extensive systems to improve biodiversity directly. Different grazing strategies can be used to manage grassland and meadow habitats to increase biodiversity of plants, insects and other species.

7.4. Sector-wide evidence gaps

Across all of the practices investigated in this REA, there were some common themes identified that are consistently limiting across multiple practices and should be addressed as a sector-wide priority.

7.4.1. Holistic herd system model

For many of the practices in this report, it is difficult to determine the overall impact of implementing a practice because of trade-offs between different elements of the suckler beef system. Often the evidence base for a practice looks only at one outcome or one part of the system and fails to consider the knock-on effects elsewhere. For example, switching from native to continental breeds produces larger cows, with greater carcass value and faster calf growth rates. However, you also have to consider that these cows have increased risk of calving difficulty, which carries a risk of injury or death to mother and/or calf, reduced colostrum intake which heightens the risk of disease, and reduced lifetime cow productivity. It is difficult to weigh up these two sides, particularly when studies only investigate one element. Furthermore, there are knock-on impacts on cull rates, calving intervals and number of replacements required, which affects profitability and environmental outcomes.

It is recommended to utilise a simple scenario modelling approach to evaluate the whole suckler beef system. The scenarios would capture the number of animals, the time they are on-farm, the amount of beef produced and the value of outputs (either cull cows or weaned calves). The model could also use this information to determine the GHG emissions and nitrate production from the system. A scenario modelling approach could then be used to change the parameters one at a time and determine the whole-herd impact on production, GHG emissions and nitrates. This would then link the KPIs, which AHDB already has a tool to calculate (Beef and lamb KPI calculators | AHDB), to productivity, profitability and environmental outcomes. Looking at how individual practices affect the KPIs would then enable an indirect quantification of the overall system impact of implementing them.

There are a number of existing modelling tools that could be adapted to enable this type of scenario modelling to be completed without the need to create a completely new model.

7.4.2. UK on-farm trials

Across all of the practices investigated, there was a lack of real, on-farm data in the UK context. The evidence base for many of these practices would be improved by identifying farms that are planning to implement the practice, document their current farm system in terms of climate, soil, system, KPIs and then record changes following the practice. While this approach is less robust than a controlled trial, it is much more cost-effective, provides useful case studies that other farms can relate to, and provides valuable real-life data on the impacts of implementing different practices. This approach would be particularly useful to understand the breed-environment interaction, such as by having a lowland farm and an upland farm keep a range of different breeds and monitor their performance in both systems.

7.4.3. Develop UK suckler beef selection indices

Within the literature, there was extensive discussion on genetics and breeding from the Irish breeding program, with lessons that can be learnt and applied to the UK context (Cromie *et al.*, no date). Beef cattle breeding in Ireland is centred around three core components: the Irish Cattle Breeding Federation (ICBF) database, genetic indices focused on profit and the G€N€ IR€LAND breeding program.

The ICBF is a non-profit organisation set up in 1998 to provide cattle breeding information services to the Irish dairy and beef industries. They set up a database in 2002 that now hold records on over 34 million animals (at time of writing) and is one of the largest and most detailed in the world. They collate information from a range of sources, including auctions, abattoirs, and animal health laboratories to provide a single comprehensive database that can feed into analysis and decision-making.

This database enabled the development of genetic indices, in partnership with Teagasc, the government-funded research, extension and education organisation. They developed three indices, each applicable to a different type of production system. The Maternal Replacement Index is optimised for producer wishing to keep female replacements and sell surplus female and all male calves for slaughter. The Terminal Index is for producers who buy in replacements and so desire an easy-calving bull with good carcass attributes, while the Dairy Beef Index is for dairy farmers looking to maximise the value of beef cross calves. A key part of these indices has been the ongoing demonstration of improved value relative to the baseline.

The G€N€ IR€LAND program is run by the ICBF in partnership with AI companies, herdbooks, pedigree bull breeders and commercial farmers. It aims to support the development of improved maternal traits within breeding bulls, which was in decline within the national herd prior to the program.

Although there are a range of suckler beef selection indices available in the UK (e.g. Genetics - Stabiliser Cattle Company; Interpreting EBVs and Indexes | Signet Breeding; Maternal Matters: EBVs and Indexes for suckler herds | AHDB), these vary in their approaches and not all are easily accessible. The creation of a harmonised database of cattle genetics covering the entire UK herd would enable the development of UK suckler beef selection indices that fit the needs of commercial farmers of different production system types. Demonstrating the value of these indices would facilitate uptake and support gradual improvements in a range of profitability-linked traits across the entire UK suckler beef sector.

7.5. Future technologies

7.5.1. Genetics and breeding

Genomics

Genomics is already well established in the dairy sector and is increasingly being applied to the suckler beef sector, although there are challenges to its uptake. Genomics involves DNA profiling of individual animals at birth by directly testing a sample of their blood or hair, allowing for the generation of breeding values. By carrying out genotyping of cattle, this allows for greater levels of genetic superiority to be achieved, as well as contributing to improvements in prediction and reliability of traits that can be selected for. It is also important to note the importance of maintaining a robust phenotyping strategy in order to maintain the accuracy of genomic estimated breeding values, as the genomic data needs to be calibrated on an ongoing basis with the phenotypic data observed and measured. Genomics is becoming increasingly accurate and cheap due to new developments in single nucleotide polymorphism (SNP) chips. Current chips can sample around 50k single nucleotide polymorphisms (variants in DNA); however, next generation sequencing (NGS) approaches could sample up to 3 million (Burnham, 2019). There are also approaches in development surrounding DNA pooling, where the DNA of the herd is pooled together and treated as one sample, and rapid sequencing, which would allow near-instantaneous results to support decision-making.

Gene editing

Gene editing using CRISPR-Cas is form of genetic modification whereby individual genes can be controlled by altering the DNA. There are a wide range of potential benefits to this technology, including improved health, welfare, and productivity; however, there are a range of technical, legislative and ethical barriers around the use of this technology in livestock systems (Menchaca *et al.*, 2020).

Sperm sorting technology

Sexed semen revolutionised the dairy sector by drastically reducing the number of male dairy calves born on farms, which have low economic value. Artificial insemination is less ubiquitous in the suckler beef sector, although uptake is increasing. One of the barriers to uptake of sexed semen is a reduction in conception rates compared to conventional AI or natural service. Improvements to the techniques used to sort sperm will help to bridge this gap and make AI more attractive to suckler beef farmers (Holden and Butler, 2018).

7.5.2. Calving and fertility

Embryo transfer

Embryo transfer involves stimulating a super-ovulation in the donor cow, following up with AI approximately one week later, and then obtaining viable embryos by 'flushing' them out of the donor cow and implanting them into a surrogate mother. There are various benefits associated with this practice, most notably that it provides farmers with access to superior genetics, as well as the ability to produce a greater number of offspring from a single high genetic cow, advancing the genetic progress of a herd at a much faster pace than could be done conventionally (Wu and Zan, 2012). This practice also has potential to provide access to a cow's genetics that may otherwise not be accessible due to reproductive difficulties if they are capable of flushing embryos. A key barrier to uptake of this practice is the high costs associated with it, as well as the value of this effort only truly being realised when using genetically superior animals, and as such may be less applicable to a wider number of suckler beef producers.

7.5.3. Feed

Feed additives

There are a range of feed additives available and in development that claim to reduce methane emissions and potentially improve livestock productivity. Four feed additives have robust evidence bases to support claims of reduced methane emissions. These are 3-NOP, an enzyme inhibitor; unprotected lipids, that change the chemistry of the rumen; essential oil blends, that interact with the rumen microbiome; and nitrate. Robust meta-analyses have shown methane reductions of 21% (Jayanegara *et al.*, 2018), 9% (Eugène *et al.*, 2008), 10% (Belanche *et al.*, 2020), and 10% (Feng *et al.*, 2020), respectively. Early experimental data for certain seaweed extracts used as feed additives have shown promise in reducing enteric emissions; for example, Abbott *et al.* (2020) reviewed the evidence base for red seaweed and found three *in vivo* studies reporting 80-95% reductions in methane in sheep, beef and dairy systems. Due to weaknesses in the experimental data (e.g. small sample sizes), the evidence is not as robust as for the other feed additives and further studies are required to determine with confidence the level of efficacy. For all additives, there is a need to overcome practical barriers to their production and use, such as how they can be incorporated into grazing systems.

Precision feeding technologies

Several studies have begun to explore the opportunity to reduce N and P excretion from cattle through diet formulation. Protein levels of 11.5–13% have been found to be optimal, suggesting that high-protein rations are to be avoided. However, protein levels that are too low run the risk of delaying growth, requiring more time on-farm, and increasing overall N excretion (Pulina *et al.*, 2021). The same review reported that reducing P rates from the actual average to the theoretical requirement as predicted by a model, decreased P input by 33-45% and P excretion by 40-50%. It is worth noting that these results are from feedlot experiments and not necessarily relevant to suckler cow feeding, which is predominantly forage-based.

7.5.4. Management

Heat detection

The benefits of AI are that it provides access to preferred genetics and allows selective mating to improve traits. It also removes the risk of bull infertility. However, AI requires close monitoring of animals to detect oestrous, making the technology time consuming. In addition, cows and heifers needs to be gathered when bulling. Artificial insemination can be combined with heat sensors to identify when animals can be inseminated (Business Wales, 2019).

There are various heat detection aids available to farmers on the market at a range of prices (Diskin, no date). Examples include simple visual indicators such as tail paint that is rubbed off, or scratch cards which can be adhered to the sacrum (tail-head) of the cow and have an illuminous colour that is revealed after other cows have mounted an animal during standing heat, with a slightly more sophisticated version of this being a patch that contains a pressure sensitive device with a timing mechanism that requires approximately three seconds for the fluid to change colour to red, signifying standing heat. The cost of these aids can be in the range of one to two pounds, and they are straightforward to implement, although perhaps less suitable in some instances, for example where cattle may be subject to low hanging branches or other environmental features that may generate false positives.

Other measures include the use of a vasectomised bull with a chin-ball marker. This marker is on a harness and marks cows during standing heat as the bull mounts them. This method is slightly more expensive with costs associated with vasectomising a bull, the management and also the upkeep of the bull; however, it can be a useful way of identifying animals that are coming into, or on, heat.

At the higher cost end of the scale there are activity monitors that make use of advanced technology and algorithms to record, analyse and identify animals that are in heat. Using neck collar sensors (and in some cases in combination with a leg sensor), activity is recorded and these aids can support a reduction in labour costs due to the cows now being monitored 24 hours a day as opposed to as many times as the farmer gets out to observe them. However, these technologies should not be solely relied upon, as they can generate false positives as well as false negatives, with many variables to account for, such as a change in daily walking distance, for example. Another option at the higher end of the price range would be pheromone sensors, although this technology is still in development. This technology would essentially serve the same function as a bull's nose by being able to detect the specific sex pheromones secreted during oestrus which would normally be a signal for the bull to know that the cow is in heat. One European source that was identified, although presented more so in the context of dairy farming, outlined that this technology could be made available for a price in the region of €1,800 to individual producers (CORDIS, 2011). While these more expensive technologies may be out of reach for some producers currently, the price of these technologies generally reduces with time. It is important to reiterate that there is no one single solution that is superior, and that a combination of heat detection methods and aids that is best suited to individual farm operations should be identified.

Geo-fencing

This technology utilises GPS collars to control where livestock graze and could be widely applicable in the suckler beef sector. The GPS has a "map" of the area where the cattle are allowed to graze, and as they approach the edge of the virtual perimeter, a mild electrical impulse is released. Over time, the cows learn where they can and cannot go, allowing the user to control their range. This technology could be particularly useful where cattle are used to manage conservation areas, while avoiding the use of fences that could hamper the movements of wildlife. Another application could be in arable systems, where cattle can be used to graze cover crops while applying organic manures to the soil without the need to build fences. This technology is already being applied as a means to implement alternative grazing patterns, although may be prohibitively expensive in most systems, costing up to £200 per collar with additional subscription packages required (*Farmers Weekly*, 2021). It is also worth acknowledging that welfare should be given due consideration in relation to this technology and that the appropriate measures are put in place to ensure welfare standards are maintained.

Artificial intelligence imaging

This practice refers to the use of cameras, coupled with artificial intelligence, to estimate information on the weight and body condition of animals. Weighing and body condition scoring require equipment and labour time, and body condition scoring relies on subjective scoring criteria that may not be consistent between scorers. The use of artificial intelligence imaging offers an objective, robust method of estimating these traits automatically with minimal time or equipment costs (Qiao *et al.*, 2021). Most of the current research into artificial intelligence imaging utilises 2D sensors to determine cattle body size and shape; however, these technologies cannot be used on moving animals (Qiao *et al.*, 2021). Using 3D sensors such as Kinect, Intel RealSense or Velodyne LiDAR enable creation of 3D models to support decision making in cattle growth monitoring. Further down the line, multi-spectral cameras could be used to begin to understand the exact fat and muscle composition of animals to provide extremely detailed nutritional recommendations.

7.6. Other practices identified

While conducting the literature search, several additional practices were identified that could be worth exploring in future work. These were:

Outwinter cows on home-grown forage

This practice provides a low-cost method of out-wintering livestock on various forage crops such as kale, fodder beet, and stubble turnips, often with a combination of baled silage. There are various benefits, most notably the alleviation of pressure on winter housing infrastructure, which can support producers that are in a phase of expansion to spread the costs of infrastructural investment over a longer time scale, or in other cases stocking rates may be increased without having to construct costly winter housing (AHDB, no date). Animal performance can be achieved that is on par with housed animals, and outwintered animals can exceed performance of in-wintered livestock in the spring as they are already acclimatised to outdoor weather conditions. In drier years with better weather over the course of the winter this method works well, with minimal impact to soil structure.

There are, however, some barriers and potential drawbacks to this practice depending on the individual scenario. It is generally more labour intensive than over-wintering cattle in sheds. Access to the field via good roads may be limited, which can have substantial effects on the amount of labour required. For example, if access to the field is poor or there is no machinery on the farm that can drive out into the field, then silage may need to be placed *in situ* earlier in the year when the ground is firmer. This also adds complexity as inaccuracies in calculations could lead to issues during the winter. Crops are generally strip grazed to minimise waste, and this is another contributing factor to increased labour costs as a new break of the crop is usually provided each day, often split into two (a morning and evening strip). However, if this practice is combined with the use of technologies such as GeoFences labour costs can be reduced – but an initial outlay is needed for the technology. Poor weather conditions can lead to complications such as damage to the soil structure in the field or movement of soils. This practice is therefore less well suited to sloped fields or in areas near to watercourses.

Pre-breeding heifer examination

The present report explored the potential benefits of pre-breeding examinations for bulls. There is also potential value in evaluation females in the herd, particularly bought in animals and those that have failed to conceive. The idea being that the examination would deliver similar benefits to bull pre-breeding, enabling removal of non- or sub-fertile animals from the herd prior to breeding.

Composite breeds

While this report explored breed selection, this was restricted to purebred beef breeds and dairy crosses, as they were studied within the body of literature. Composite breeds are a cross between two or more established pedigree breeds to create a new breed, in theory with the best traits of both parent lines. One popular example is the Stabiliser, originally developed in the US as a cross between Hereford, Angus, Simmental and Gelbvieh. The breed claims a range of productivity benefits compared to other breeds, such as smaller mature cow size, higher fertility, lower age at first calving, higher growth rates, improved feed efficiency and lower GHG emissions. Some data has been published to support these claims (*Stabiliser Cattle Company*, 2016; 'Stabiliser Cattle Company', 2020), but independent trials are needed to verify the data.

Health and disease

This REA also deliberately excluded practices relating to health and disease to constrain the scope of the project. This is an area that could have potentially large influence on the productivity, profitability, environmental impact and welfare of cattle in suckler beef herds and would also be worth including in future work.

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