*Translational Animal Science*, 2022, **6**, 1–16
https://doi.org/10.1093/tas/txac077
Advance access publication 6 June 2022
**Review**

# Economic assessments from experimental research trials of feedlot cattle health and performance: a scoping review

**Andrea L. Dixon,[†,‡] Christy J. Hanthorn,[†,‡] Dustin L. Pendell,[†,‖] Natalia Cernicchiaro,[†,‡] and David G. Renter[†,‡,1]**

[†]Center for Outcomes Research and Epidemiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506, USA
[‡]Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506, USA
[‖]Department of Agricultural Economics, College of Agriculture, Kansas State University, Manhattan, KS 66506, USA
[1]Corresponding author: drenter@vet.k-state.edu

## ABSTRACT

Animal husbandry decisions for feedlot cattle may be based on economic or financial impacts reported from livestock research trials comparing interventions such as health practices or performance technologies. Despite the importance of economic assessments to production management decisions, there are no consensus guidelines for their methods or reporting. Thus, we hypothesized that methods and reporting of economic assessments in the scientific literature are inconsistent. This scoping review describes the types of economic assessments used to evaluate the costs and benefits of interventions in feedlot trials, how measured health and performance outcomes are utilized in economic evaluations, and the completeness of reporting. A structured search was used to retrieve peer-reviewed articles (published in English) on experimental trials performed in Australia, North America, or South Africa, which reported feedlot cattle health, performance, or carcass characteristics and included an economic outcome. A total of 7,086 articles were screened for eligibility; 91 articles (comprising 113 trials) met the inclusion criteria. Trial characteristics, methods, and reporting data were extracted. A primary outcome was stated in only 36% (41/113) of the trials. Of these 41 trials, an economic outcome was reported as a primary outcome in 18 (44%). Methodology for the economic assessment was reported for 54 trials (48%), the type of economic assessment was explicitly stated for 21 trials (19%), and both the type of economic assessment and methodology used were reported for 29 trials (26%); neither were reported for nine trials (8%). Eight types of economic assessments were explicitly reported: cost-effectiveness, cost–benefit analysis, enterprise analysis, partial budget, break-even analysis, profitability, decision analysis, and economic advantage. From the trials that did not report an assessment type, three were identified: partial budget, enterprise analysis, and gross margin analysis. Overall, only 32 trials (28%) reported economics as an outcome of interest, the methodology used or the type of assessment, and values, sources, and dates for at least some of the price data used in the analysis. Given the variability in methods and inconsistent reporting for feedlot trials identified by this scoping review, a guideline to facilitate consistency on appropriate methods and reporting is warranted.

**Key words:** economic analysis, feedlot trials, financial analysis, scoping review

## INTRODUCTION

Experimental research, such as randomized field (clinical) trials, provide strong evidence of causation and are especially suited to evaluate the efficacy or effectiveness of interventions that aim to improve animal health, performance, food safety, and other outcomes of importance to livestock production systems (Sargeant et al., 2010). Economic or financial outcomes are often important drivers of management decisions regarding the adoption or implementation of interventions within a production system. Within feedlot production systems, an assessment of economic outcomes is often the primary goal of a field trial in which two or more health or production management strategies are compared. Although appropriate inferences or management decisions based on results of feedlot trials require valid research and transparent reporting (Sargeant et al., 2010), there are no established guidelines regarding economic or financial assessments to ensure the research methods and results are performed and reported accurately.

Guidelines for reporting economic assessments in human health studies, such as the Consolidated Health Economic Evaluation Reporting Standards (CHEERS; Husereau et al., 2013), have been established. In addition, there have been a variety of resources and guidelines established for reporting research on animals, such as the reporting guidelines for randomized controlled trials for livestock and food safety (REFLECT; O'Connor et al., 2010; Sargeant et al., 2010), with several of these resources currently provided at the MEnagerie of Reporting guIDelines Involving Animals (MERIDIAN) website (https://meridian.cvm.iastate.edu/). In general, these guidelines aim to improve the reproducibility and reporting of research studies so that the results are more useful for stakeholders. However, neither CHEERS, due to the often differing objectives for economic analyses for human health compared to livestock production (Babo Martins and Rushton, 2014; Sanghera et al., 2015), nor any of the established guidelines or standardized approaches for animal research directly facilitate the accurate reporting of research

Received March 3, 2022 Accepted June 2, 2022.

methods and results when economic or financial assessments are a critical component of the livestock field trial.

Given the practical importance of economic assessments in livestock field trials, yet the gap in the literature regarding guidelines for this research area, we hypothesized that numerous publications would exist, but the reporting of key components would not be consistent. Since no previous research has assessed the reporting of feedlot trials with economic results, we performed a scoping review, which is a systematic and transparent approach to chart and assess published literature on a defined topic (Levac et al., 2010; Tricco et al., 2018). The two primary objectives of this scoping review were to chart: 1) the types of economic assessments used to evaluate the costs and benefits of interventions on beef cattle health and performance metrics measured in a feedlot or corresponding carcass characteristics, from experimental trials, and 2) how these measured health and performance outcomes are utilized in the trials' economic assessments. The secondary objective was to summarize how the economic assessment methodology was reported regarding the reproducibility of the analysis.

## MATERIALS AND METHODS

This scoping review was carried out utilizing the framework of Arksey and O'Malley (2005), with the recommendations of Levac et al. (2010), except no stakeholder consultations were performed. A protocol for this scoping review was developed a priori by group discussion among coauthors. This protocol, along with recorded alterations and rationales, is presented in Supplementary Material 1.

### Article Sources

In April 2020, articles were identified through a search of four electronic databases: CAB Direct (1930 to 2020), Web of Science – CORE collections (1945 to 2020), Scopus (1800s to 2020), and Pubmed (1950 to –2020), using the database's default time frame, through the Kansas State University library. The CAB Direct and Scopus databases were chosen as they give the most comprehensive coverage of important veterinary medicine journals and we included Web of Science and PubMed to be as comprehensive as possible in our search (Grindlay et al., 2012). Citation information and abstracts from the database searches were exported into a spreadsheet program (Microsoft Excel), with each article assigned a unique identification number. Duplicates were manually removed. In addition to the database search, any relevant systematic reviews or meta-analyses that were identified from the search had their references hand-searched for relevant articles that fit the eligibility criteria; however, only original research was included in the scoping review. Any relevant articles from the authors' personal collections that were not previously identified by the database search nor from a review or meta-analysis evaluation also were included.

### Eligibility Criteria

Articles were eligible for inclusion if they had been published in a peer-reviewed journal and written in English. Our population of interest was beef cattle housed in feedlot operations in Australia, North America (Canada, United States of America, and Mexico), or South Africa. We defined beef cattle as non-dairy breed cattle raised exclusively for beef. Dual-purpose breeds were included only if it was conclusive that they had been raised for beef consumption and not milk production. We defined a "feedlot" based on the Environmental Protection Agency's (EPA) definition of an animal feeding operation (EPA, n.d): animals needed to be, or would have been if not for the length of the trial in place, confined and fed for 45 d or more and pre-harvest crops raised at the facility were not used as the primary diet source for cattle. We limited our study locations to the primary areas of large-scale commercial feedlot production in order to ascertain that animals were under management representative of large-scale commercial beef feedlots. The beef industries in these areas utilize a finishing phase where cattle, in operations generally housing more than 1,000 animals, are fed high-grain diets in densely confined non-pastured lots (United States Department of Agriculture, n.d; Australian Lot Feeders Association, n.d; South African Feedlot Association, n.d; Statistics Canada, n.d).

Articles were eligible if they included results from experimental trials, performed at either a research or commercial feedlot facility, and a health and/or performance metric measured in a feedlot and/or carcass characteristic was measured as the outcome of interest(s). Additionally, articles reporting an economic/financial outcome, defined as a monetary cost or benefit from an assessment of an intervention on feedlot outcomes, were deemed eligible.

### Search Terms

The question of interest was: what types of economic/financial assessments have been used to evaluate the costs and benefits of interventions on beef cattle health and performance metrics from experimental field trials? The search strategy was developed to target articles that included experimental studies AND beef cattle AND economic analysis, as search terms. The exact search terms were developed through discussion with the coauthors defining the eligibility criteria and then using an iterative strategy, where a set of terms were identified and the returned titles were assessed for broad compliance and the inclusion of known articles that fit the eligibility criteria. The terms were then updated and the search re-deployed assessing the returned titles until all known articles were found and there was little improvement in title relevance. Search terms for the four database searches are reported in Table 1.

### Relevance Screening

Two rounds of relevance screening were performed using a list of questions, created using our eligibility criteria and refined through group discussion with coauthors, to guide the screening process (Supplementary Material 1, section "Selection process"). In the first round, two reviewers independently evaluated the title and abstract of all articles. The full-texts from articles included after the first round were retrieved. In the second round, the full-text of each article was also screened in duplicate. Disagreements between the two reviewers' answers were resolved through discussion and if a consensus could not be reached a third reviewer was consulted.

### Data Extraction Process

Based on group discussion between coauthors, we created and refined the data extraction form, which defined the data items to be extracted. The final data extraction form, approved responses, alterations, and rationales are available from authors upon request. Two reviewers independently extracted data items from relevant full-text articles into a spreadsheet

**Table 1.** Databases and the respective search strategies used in this scoping review

| Database | Interface | Dates included[1] | Search terms |
|---|---|---|---|
| CAB Direct[2] | CAB Direct | 1930–2020 | All fields = ((cattle OR "cow-calf" OR "feed lot" OR "feed lots" OR feedlot* OR ((calves OR calf) NOT human) OR cow* OR steers OR bull OR beef) NOT ("cowpea" OR lamb OR goat OR dairy OR buffalo OR camel)) AND ("field trial" OR "clinical trial" OR "experimental trial" OR randomized OR randomization OR trial) AND ("economic analysis" OR "financial analysis" OR economic* OR cost OR price OR "willingness to pay" OR benefit OR minimization OR effectiveness OR consequence) |
| Web of Science – CORE collections | Web of Science | 1945–2020 | TS=((cattle OR "cow-calf" OR "feed lot" OR "feed lots" OR feedlot* OR ((calves OR calf) NOT human) OR cow* OR steers OR bull OR beef) NOT ("cowpea" OR lamb OR goat OR dairy OR buffalo OR camel)) AND (TS=("economic analysis" OR "financial analysis" OR economic*) AND (cost OR price OR "willingness to pay" OR benefit OR minimization OR effectiveness OR consequence)) AND TS=("field trial" OR "clinical trial" OR "experimental trial" OR randomized OR randomization OR trial) AND LANGUAGE: (English) |
| Scopus | Elsevier | 1800s–2020 | TITLE-ABS-KEY((cattle OR "cow-calf" OR "feed lot" OR "feed lots" OR feedlot* OR ((calves OR calf) AND NOT human) OR cow* OR steers OR bull OR beef) AND NOT ("cowpea" OR lamb OR goat OR dairy OR buffalo OR camel)) AND ("field trial" OR "clinical trial" OR "experimental trial" OR randomized OR randomization OR trial) AND ("economic analysis" OR "financial analysis" OR economic* OR cost OR price OR "willingness to pay" OR benefit OR minimization OR effectiveness OR consequence) AND LANGUAGE(English) AND AFFILCOUNTRY("United States of America" OR australia OR "South Africa" OR mexico OR canada) |
| Pubmed | NCBI | 1950–2020 | All fields ((cattle OR "cow-calf" OR "feed lot" OR "feed lots" OR feedlot* OR ((calves OR calf) NOT human) OR cow OR cows OR steers OR bull OR beef) NOT ("cowpea" OR lamb OR goat OR dairy OR buffalo OR camel)) AND ("field trial" OR "clinical trial" OR "experimental trial" OR randomized OR randomization OR trial) AND ("economic analysis" OR "financial analysis" OR economic* OR cost OR price OR "willingness to pay" OR benefit OR minimization OR effectiveness OR consequence) AND ENGLISH[LANGUAGE] |

TS = Topic; searches abstract, author keywords, and Keywords Plus.
[1]Searches were not limited by date and the range presented is inclusive of each database's default timeframe searched. The search took place April 2020.
[2]Includes CAB Abstracts, Global Health, VetMed Resource, CABI Full Text, Distribution Maps Plant Diseases, CAB eBooks Archive 2008–2010, Animal Health and Production Compendium (AHPC), eBook Choice Kansas State Collection.

program (Microsoft Excel). If an article contained information regarding more than one experimental trial, data were extracted for each trial individually. If there was disagreement between the reviewers in terms of data extracted, a consensus was reached using the same process described for the screening process. Authors of articles were not contacted to obtain any additional information.

## Extracted Data Items and Explanations

A summary of the data items extracted is presented in Table 2 and detailed explanations are given in this section. Except for citation information, all data items were extracted at the trial level and a single article could include information from multiple trials.

*Location and animal management items* Information about the country where the trial took place and the U.S. state or province/territory, for non-U.S. countries, was extracted as reported in the article or if only a city name was reported, the reviewers confirmed the country and state/province/territory where the city is located. If a trial took place in more than one state/province/territory, it was marked as "multiple." If geographic location and/or type of facility where the trial took place was not reported in the text, the reviewers first attempted to extract the information from the article authors' affiliation(s) and/or acknowledgement. If this was ambiguous, the following decisions were made: the reviewers extracted the country and state/province/territory of the article authors' affiliated institution for these respective items, if there was more than one state/province/territory represented by the article authors' affiliated institutions then the state/province item was reported as missing. If the facility type where the trial took place could not be determined from the affiliation and/or acknowledgement then it was reported as missing.

For the pen/paddock size, if a capacity range for each pen/paddock was reported, this information was extracted, unless the actual number of animals allotted to each pen/paddock was higher than the given capacity, then the exact number allocated was extracted for this item. If only the number of animals allocated to each pen/paddock was reported, this datum was extracted.

*Intervention and study design items* For the total number of animals in the trial, reviewers extracted all applicable information that was reported. If the total number of animals was not reported, reviewers marked this item as missing unless it was possible to unambiguously calculate the total (e.g., 30 animals in treatment A and 30 animals in treatment B for 60 total animals). Reviewers extracted the production stage when the intervention was applied using the following criteria to differentiate between stages: interventions applied to the dam and/or to the calf pre-weaning were deemed as "cow-calf," weaning management or interventions

**Table 2.** Summary of the key data items and their description, by the level at which they were extracted

| Article level | Description |
|---|---|
| Citation information | The name of the first author, a list of all authors, title, journal name, and publication date |
| **Trial level** | |
| Country and state/province | The country the trial took place: Australia (AUS), Canada (CAN), Mexico (MEX), South Africa (SAFR), or the United States of America (US). The U.S. state or territory/province, for non-US countries, was also extracted. |
| Site type | Whether the trial was performed at a research ("research") or commercial ("commercial") facility. |
| Pen/paddock size | The article authors' reported capacity range for each pen/paddock or the reported number of animals allotted to each pen/paddock was categorized as "≤ 15," "16–50," "51–350," "≥ 351," "pen size varied," or "unspecified". |
| Trial size | The total number of animals in the trial as reported by the authors. |
| Production stage when the intervention was applied | The production stage when the intervention was applied using the following categories: cow-calf, backgrounder or stocker, and feedlot. |
| Intervention | Interventions were categorized as vaccination, parenteral antimicrobials, parasite control, feeding, management, and multiple interventions. |
| Statement of primary and secondary objectives | "Yes" if: the article authors had unambiguously stated their primary and secondary objectives(s), if applicable, there was only one outcome measured, or the article authors reported a sample size/power analysis in which case the outcome used in the calculation was assumed to be the primary outcome and all other outcomes were placed as secondary if stated in the objectives; otherwise this data item was recorded as "no." |
| The outcomes of interest | Outcomes were categorized as carcass, economic, health, and live performance. |
| Animal outcomes used to derive the cost/benefit of the intervention; if they were a stated primary objective | Which of the measured outcomes were used to derive the cost and benefits of the intervention using the categories: "all," "significant only," "some," "none," or "not reported." If the outcomes used to determine the cost and benefits of the intervention were "significant only" or "some," the reviewers extracted if at least one of these outcomes were included in the article authors' stated primary objectives ("yes"/"no"). If the article authors did not report their primary objective(s), it was extracted as "not reported." |
| If the analytic methods for the economic/financial assessment were reported | If the economic/financial assessment methods as reported had enough information to be repeated ("yes"/"no"). |
| If the authors reported the type of economic assessment used | If the article authors identified the type of economic assessment used ("yes"/"no"). |
| Type of economic assessment used | As reported in the text by the article authors or if the type of economic assessment was not reported, the methods were categorized by a content expert (i.e., agricultural economist) as "gross margin analysis," "enterprise budget," "break-even analysis," "partial budget," "decision analysis," or "cost–benefit analysis." |
| Values used in the economic assessment reported | If "all," "some," or "none" of the values used in the economic/financial assessment were reported. |
| Research methods or sources for value described and/or cited; type of sources used | If "all," "some," or "none" of the values or methods used in the economic/financial assessment were sourced. If "all" or "some" of the values were sourced, the source was categorized as "public," "private," or "commercial service." |
| Dates the values were estimated and/or sourced reported | If the date of the values were estimated and/or sourced was reported ("yes"/"no"). |

applied to young/light weight cattle in drylots or on pasture before the finishing stage were defined as "backgrounder or stocker," and if the intervention was applied to group-penned cattle at the finishing stage, including interventions applied during processing such as prophylaxis and metaphylaxis, were classified as "feedlot." If multiple interventions were applied at different production stages, information from all stages was extracted.

The reviewers recorded the intervention applied in the trial as reported by the authors and created the following categories based on the extracted interventions: vaccination, parenteral antimicrobial, parasite control, feeding, management, and multiple interventions. Vaccination interventions included comparisons of a vaccine to a control or to another product, as well as the timing of vaccine administration. Parenteral antimicrobial interventions included comparisons of injectable antimicrobials used for metaphylaxis, disease treatment, or both. Parasite control interventions included comparisons between de-worming products as well as the effect of the magnitude of parasite burden. Feeding interventions included the following: comparisons among diets, feedstuffs, or feeding strategies, the effects of feed additives (e.g., beta-agonists, ionophores, melengestrol acetate [MGA], and antimicrobials) or supplements, or a combination of these feeding interventions. Management interventions included investigation of the effects of pre-conditioning systems, feedlot management systems, abortion of feedlot heifers, sorting, shade, administration of implants, and exposure to cattle that are persistently infected with bovine viral diarrhea virus. If interventions of multiple categories were applied, the trial intervention was categorized as "multiple."

Outcomes were categorized into one of four categories: carcass (e.g., hot carcass weight, yield and quality grades), economic (i.e., any financial or economic objective), health (e.g., morbidity, mortality rate, antibody titers), and live performance (e.g., average daily gain, dry matter intake, body weight). We used these broad groups for ease of reporting, as our objective was to chart how health and performance outcomes are used in economic/financial assessments not which specific health/performance outcomes are used. If primary and secondary outcomes were stated ("yes"), the outcome category was further defined as "primary outcomes," "secondary outcomes," and/or "outcomes that were measured, but not reported in the objectives" (i.e., any outcome that was reported in the text, but not referenced in the objective statement). If primary and secondary outcomes were not stated ("no"), the outcomes were further defined as the "outcome(s) of interest" and/or "outcomes that were measured, but not reported in the objectives." A single trial could contain multiple types of outcomes (e.g., "primary outcome" and "secondary outcome") and these could be from the same category (e.g., health).

*Economic/financial assessment items* The reviewers extracted if the values used in the economic/financial assessment were reported and if the source or methods to calculate that value were reported; categorizing the source/methodology as a "public," "private," or "commercial service." Public sources included any report or publication that is in the public sphere (e.g., journal articles, government reports), private sources were values unique to the trial, facility, and/or producer (e.g., feedlot receipts, producer specific carcass grids), and commercial services were sources that are available to paying members of an association or group (e.g., Canfax). The reviewers also extracted if the dates the values were sourced/estimated were reported ("yes"/"no"). This received a "yes" if it was stated, but also if the article authors reported the values were privately or commercially sourced and the date of the trial was also reported; otherwise, it received a "no." The reviewers used text, tables, and footnotes to assess questions pertaining to values and sources.

## RESULTS AND DISCUSSION

### Article Retrieval

A total of 8,244 articles were identified from the four database searches and 1,315 duplicates were removed. From the unique articles ($n$ = 6,929), 138 eligible reviews were identified; 18 reviews were not searched—10 were specific to noneligible locations and 8 could not be retrieved. The reference lists of 120 reviews were searched by hand and 158 new articles were identified. One article could not be accessed; therefore 157 articles' titles and abstracts were added ("Relevance Screening: Title and abstracts" phase; Figure 1). From the 7,086 titles and abstracts that were screened, 184 articles were deemed relevant. During the full-text screen, three additional reviews were identified and their reference lists hand-searched. One relevant article was identified and included in the full-text screen of 191 articles ("Relevance Screening: Full-text"; Figure 1). From the full-text screen, 91 articles met the eligibility criteria and were charted, whereas 100 articles were removed; reasons for removal are listed in Figure 1.

### Characteristics of Articles

From the 91 articles that were charted, the median year of publication was 2005 and ranged from 1967–2018 (see Supplementary Figure 1 in Supplementary Material 2). Most of the articles were published in 2008 ($n$ = 13). Nineteen journals were represented in the scoping review, and over half of the articles (59%) were published in three journals: The Professional Animal Scientist (22%; $n$ = 20), Journal of Animal Science (21%; $n$ = 19), and The Canadian Veterinary Journal (16%; $n$ = 15) (see Supplementary Table 1 in Supplementary Material 2). Although it limits the scope of this review, including peer-reviewed articles only, as opposed to also including "grey literature," increases the rigor of the reported results and minimizes bias. Efforts were made to include not only peer-reviewed articles retrieved from databases encompassing agricultural research but also via hand search of relevant review articles.

### Characteristics of Trial Populations

One hundred and thirteen eligible trials were identified from the 91 articles. Sixty-seven trials (59%) were performed in the United States, 42 (37%) in Canada, and four (4%) in South Africa. Limiting the geographical scope of the review and excluding regions with growing feedlot industries, such as Brazil, Argentina, or Uruguay, resulted in the exclusion of potential eligible articles. However, the aim of this review was to describe trials from geographic regions with large commercial feedlot industries traditionally similar to those found in the United States. Historically, Brazil has been largely pastoral, with intensification of the beef industry occurring predominately in the last couple of decades (Millen et al., 2011). Lastly, and related to the geographical location, the exclusion of non-English publications further limits the scope of our findings.

Fifty percent of trials (57/113) were performed at a commercial facility, 37% (42/113) at a research facility, and the type of facility used was not reported for 12% (14/113) of trials. Overall, the median number of animals per trial was 361 and ranged from 22 to 19,099. Commercial facilities performed larger trials with a median trial size of 1,010 animals (range = 103 to 19,099), whereas trials performed at research facilities had a median trial size of 215 animals (range = 22 to 2,659). Trials at unspecified facility types had a median trial size of 143 animals (range = 64 to 774). Sixty-six percent of commercial trials (38/57) used pen sizes that held 51 to 350 animals, whereas 43% (18/42) of research trials and 50% (7/14) of trials at unspecified facilities used pen sizes that held up to 15 animals. Overall, pen sizes of 51 to 350 animals were used in 36% (41/113) of trials, the number of animals allocated per pen was not specified in 26% (30/113), and pen sizes of up to 15 animals were used in 23% (26/113) of the trials. Interventions were applied at the feedlot stage in 80% (90/113) of the trials, whereas interventions were applied at the background or stocker stage, at the cow-calf stage, or at multiple stages in the other 20% (23/113) of the trials. Trials by production stage at intervention, type of intervention, and pen/paddock size are presented in Table 3.

### Characteristics of Trial Reporting

Primary outcome(s) were not stated for 64% (72/113) of the trials; although not as an outcome of interest, an economic/financial outcome was reported for 18% (13/72) of

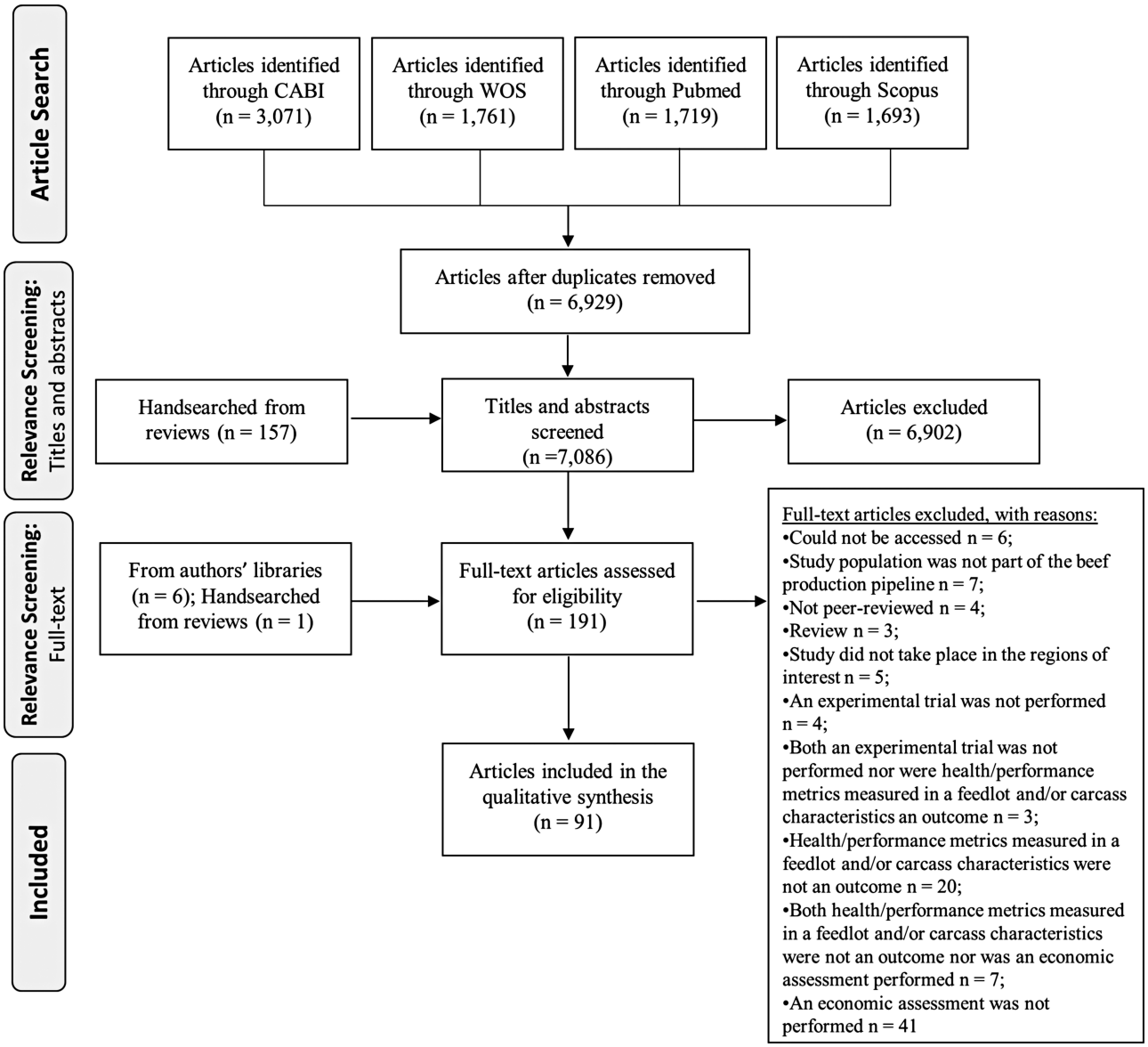


**Figure 1.** A flow chart of the number of articles identified, screened for eligibility through two rounds of relevance screening, a title and abstract screen and a full-text screen, and the final number of articles retained for data extraction. The number of articles excluded by the eligibility screening with reasons are detailed.

these trials. Primary outcomes were reported for 41 trials; 44% (18/41) included an economic/financial outcome as a primary outcome and 34% (14/41) included an economic/financial outcome as a secondary outcome. An economic/financial outcome was reported, but not stated as a primary or secondary outcome of interest, for nine trials (22%; 9/41). All reported outcomes and how they were reported are presented in Table 4.

As part of the data extraction, we used an explicit set of criteria to determine primary and secondary objectives. Whereas this was necessary for systematic extraction, often author language or reporting did not directly fit the terminology or criteria that we had defined. As a result, the 72 trials charted as not stating their primary outcome may be over-represented. However, the ambiguity of reporting the primary objective in 64% of the trials underscores the need for standardized reporting guidelines and the need to adopt the use of such guidelines. These 72 trials belonged to 57 articles, 14 (25%) of which were published after 2010, when REFLECT guidelines were made available. Overall, an economic/financial outcome was reported as an outcome of interest in 91 trials (81%), whereas 22 trials (19%) reported an economic/financial outcome, but did not state that it was an outcome of interest.

The distribution of the reporting of the economic/financial methodology of the trials by whether or not an economic/financial outcome was stated as an outcome of interest is presented in Table 5. In addition to categorizing if the methodology and/or type of economic assessment were described, we also extracted if a statistical test was used to evaluate the economic/financial difference between treatments; a statistical evaluation was used in 44% (50/113) of the trials. The inclusion of a statistical evaluation of the cost/benefit of the treatment, if performed and reported appropriately, is of added value to the stakeholder as it provides estimates and, more importantly, the degree of uncertainty around those estimates.

**Table 3.** The number of trials ($n$ = 113) by production stage at intervention, type of intervention, and housing group size with citations

| Production stage at intervention | Intervention | Pen/paddock size | *N* | Citations |
|---|---|---|---|---|
| Cow-calf ($n$ = 7) | Feeding | ≤ 15 | 1 | Larson et al., 2009 |
| | | Unspecified | 2 | Mulliniks et al., 2012; Stalker et al., 2006 |
| | Management | Unspecified | 3 | Karren et al., 1987; Peterson et al., 1989 |
| | Vaccination | Unspecified | 1 | Kirkpatrick et al., 2008 |
| Cow-calf and backgrounder or stocker ($n$ = 2) | Management | Unspecified | 1 | Shike et al., 2007 |
| | Multiple | 16–50 | 1 | Anderson et al., 2005 |
| Cow-calf and Feedlot ($n$ = 1) | Vaccination | Unspecified | 1 | Bechtol et al., 1991 |
| Backgrounder or stocker ($n$ = 8) | Feeding | ≤ 15 | 2 | Forte et al., 2018; Mir et al., 2008 |
| | | Unspecified | 3 | Parish et al., 2013; Lewis et al., 1990; Bedwell et al., 2008 |
| | Management | Unspecified | 3 | McCartney et al., 2008 |
| Backgrounder or stocker and Feedlot ($n$ = 5) | Feeding | ≤ 15 | 3 | Berthiaume, 2006; Şentürklü et al., 2018; Lewis et al., 1990 |
| | | Unspecified | 2 | Gillespie-Lewis et al., 2016 |
| Feedlot ($n$ = 90) | Feeding | ≤ 15 | 8 | Price et al., 1978; Xiong et al., 1991; Bartle et al., 1994; Flatt et al., 2003; Sawyer et al., 2004; Swyers et al., 2014; Loerch and Fluharty, 1998; Hinman et al., 1999 |
| | | 16–50 | 2 | Rivera et al., 2018 |
| | | 51–350 | 6 | Gallo and Berg, 1995; Vázquez-Añón et al., 2007; Perrett et al., 2008b; Van Donkersgoed et al., 2011; Van Donkersgoed et al., 2014; Sides et al., 2009 |
| | | Unspecified | 5 | Louis et al., 1988; Dubeski et al., 1997; DeRouen and Foster, 2006 |
| | Management | ≤ 15[1] | 4 | Jim et al., 1991; Elam et al., 2008; Step et al., 2008; Cooprider et al., 2011 |
| | | 51–350[2] | 4 | Edwards and Laudert, 1984; Macken et al., 2003; Blaine and Nsahlai, 2011; Kononoff et al., 2015 |
| | | Unspecified | 1 | Kadel et al., 1985 |
| | Multiple | ≤15 | 5 | McEwen et al., 2007; Stanton et al., 1989; Sawyer et al., 2003; Lefebvre et al., 2006 |
| | | 51–350 | 2 | Macken et al., 2003 |
| | Parasite control | ≤15 | 3 | Grimson et al., 1987; Campbell et al., 1987; Williams et al., 1991 |
| | | 16–50 | 4 | Grimson et al., 1987; Alexander and Miller, 1972 |
| | | 51–350 | 6 | Flack et al., 1967; Schunicht et al., 2000; MacGregor et al., 2001 |
| | | ≥351 | 2 | Flack et al., 1967 |
| | | Pen size varied | 1 | Guichon et al., 2000 |
| | | Unspecified | 5 | Bauck et al., 1989; Soll et al., 1991; Leland et al., 1980; Wellington and Van Schalkwyk, 1982 |
| | Parenteral antimicrobial | 16–50 | 1 | Hannon et al., 2009 |
| | | 51–350 | 17 | Mechor et al., 1988; Jim et al., 1992; Jim et al., 1999; Schunicht et al., 2002a; Schunicht et al., 2002b; Booker et al., 2007; Van Donkersgoed et al., 2008a; Van Donkersgoed et al., 2008b; Abutarbush et al., 2012; Van Donkersgoed and Merrill, 2012; Van Donkersgoed et al., 2013; Van Donkersgoed and Hendrick, 2013; Van Donkersgoed and Merrill, 2013a; Van Donkersgoed and Merrill, 2013b; Tennant et al., 2014; Van Donkersgoed et al., 2017 |
| | | Pen size varied | 3 | Booker et al., 2006; Schunicht et al., 2007; Perrett et al., 2008a |
| | | Unspecified | 2 | Stegner et al., 2013; Booker et al., 1992 |
| | Vaccination | 51-350 | 6 | Gummow and Mapham, 2000; Schunicht et al., 2003; Bryant et al., 2008; Perrett et al., 2008c; Wildman et al., 2008; Rogers et al., 2015 |
| | | Pen size varied | 2 | MacGregor and Wray, 2004; Wildman et al., 2009 |
| | | Unspecified | 1 | Bechtol et al., 1991 |

[1]In one trial (Step et al., 2008), 13–16 animals were housed per pen.
[2]One trial (Kononoff et al., 2015) reported 52 head per pen plus or minus 5.69 head.

**Table 4.** The number and percentages of trials by outcomes of interest and how they were reported

| Primary outcomes stated ($n$ = 41) | | | | |
|---|---|---|---|---|
| **Primary outcome(s)** | **Secondary outcome(s)** | **Outcome(s) measured, but not stated as outcome(s) of interest** | **Outcome(s) used in the economic/financial assessment, but not stated as outcome(s) of interest** | **N (%)** |
| Economic | - | - | Carcass, Live perf. | 5 (12.2) |
| Health | - | Economic | - | 4 (9.8) |
| Health | Economic | - | - | 4 (9.8) |
| Health | Economic, Live perf. | - | - | 4 (9.8) |
| Economic | - | - | Health, Live perf. | 3 (7.3) |
| Economic | - | - | Live perf. | 3 (7.3) |
| Economic | - | - | Carcass, Health, Live perf. | 2 (4.9) |
| Carcass | Economic | - | - | 1 (2.4) |
| Carcass | Economic, Live perf. | - | - | 1 (2.4) |
| Carcass, Live perf. | Economic | - | - | 1 (2.4) |
| Carcass, Live perf., Health[1] | - | Economic | - | 1 (2.4) |
| Economic | - | - | Carcass | 1 (2.4) |
| Economic | - | - | Carcass, Health | 1 (2.4) |
| Economic | Health | - | Carcass, Health, Live perf. | 1 (2.4) |
| Economic | Health | - | Live perf. | 1 (2.4) |
| Economic, Health | | - | Carcass, Live perf. | 1 (2.4) |
| Health | Carcass, Economic, Live perf., Health[2] | - | - | 1 (2.4) |
| Health | Live perf. | Economic | - | 1 (2.4) |
| Health | - | Economic, Live perf. | - | 1 (2.4) |
| Health | - | Carcass, Economic, Live perf. | - | 1 (2.4) |
| Health, Live perf. | - | Economic | - | 1 (2.4) |
| Live perf. | Economic, Health | - | - | 1 (2.4) |
| Live perf. | Carcass, Economic, Health | - | - | 1 (2.4) |

| Primary outcomes not stated ($n$ = 72) | | | |
|---|---|---|---|
| **Outcome(s) of interest** | **Outcome(s) measured, but not stated as outcome(s) of interest** | **Outcome(s) used in the economic/financial assessment, but not stated as outcome(s) of interest** | **N (%)** |
| Carcass, Economic, Live perf. | - | - | 18 (25.0) |
| Carcass, Economic, Health, Live perf. | - | - | 10 (13.9) |
| Economic, Live perf. | - | - | 8 (11.1) |
| Economic, Health, Live perf. | - | - | 7 (9.7) |
| Carcass, Health, Live perf. | Economic | - | 7 (9.7) |
| Economic, Live perf. | Health | - | 6 (8.3) |
| Carcass, Economic, Live perf. | Health | - | 4 (5.6) |
| Carcass, Live perf. | Economic | - | 4 (5.6) |
| Carcass, Economic, Health | - | - | 1 (1.4) |
| Carcass, Economic, Health | Live perf. | - | 1 (1.4) |
| Carcass, Economic, Live perf. | - | Health | 1 (1.4) |
| Carcass, Live perf. | Economic, Health | - | 1 (1.4) |
| Economic, Health | - | - | 1 (1.4) |
| Economic, Health | Carcass, Live perf. | - | 1 (1.4) |
| Economic, Health, Live perf. | Economic[3] | - | 1 (1.4) |
| - | Carcass, Economic, Live perf. | - | 1 (1.4) |

Live perf. = Live Performance
[1]Carcass, live performance, and health were all stated as outcomes of interest, but a primary outcome was not identified.
[2]Two different health outcomes were stated as a primary and secondary outcome of interest.
[3]An economic/financial outcome was stated as a primary outcome of interest and another economic/financial outcome was also reported, but not stated as an outcome of interest.

Of the 22 trials which had economic/financial outcomes reported, but were not stated as an outcome of interest, 17 (77%) reported the methodology for the assessment, whereas 5 (23%) reported only the type of economic assessment used (Table 6). One plausible explanation for this discrepancy is that these studies were not designed to include an economic/financial outcome; as such the outcome and affiliated analysis were included after the study had been completed as an added value after observing differences in health or performance outcomes, or possibly if a reviewer requested an economic/financial value during the publication process. Despite not stating the economic/financial outcome as an outcome of interest, some type of methodology information was reported for all 22 of these trials. Of the nine trials where no methodology was reported, but did state an economic/financial outcome as an outcome of interest (Table 6), only one reported it as the primary outcome. Six of these nine trials came from a single article which only provided some methods for one of the two economic/financial outcomes reported. The four articles that comprised these nine trials were published in years 1967, 1978, 1987, and 2004. Here, the lack of methodology and statement of primary objectives is likely due to poor and unstandardized reporting, especially prevalent in older papers, causing ambiguity and/or discrepancies in the interpretation of the methods and results. Adapting current guidelines, or creating new ones, would be beneficial to researchers and stakeholders as it would support the improvement of economic analyses reporting in livestock research (Totton et al., 2018).

Answering our first primary objective, to chart the types of economic assessments reported in the literature, there were eight types of economic assessments reported by the authors: cost-effectiveness/relative cost-effectiveness ($n$ = 25), cost–benefit analysis ($n$ = 8) including "cost–profit analysis" and "cost-to-benefit ratio", enterprise analysis ($n$ = 5), partial budget ($n$ = 5), break-even analysis ($n$ = 3), profitability ($n$ = 3), decision analysis ($n$ = 1), and economic advantage ($n$ = 1). Without clear descriptions of the economic assessments, through definitions and transparent methods, we wanted to avoid over interpretation and chose to only extract the assessments as reported by the articles' authors. For example, the most commonly reported economic assessment was

**Table 5.** The number of trials ($n$ = 113) grouped by and across reporting of the economic/financial assessment methodology, type of economic assessment, and if the economic/financial difference between treatments was evaluated with a statistical model by whether the economic/financial outcomes were reported or not as an outcome of interest

| Economic/financial outcome stated as an outcome of interest | Methodology reported ($n$ = 83)[1] | | | | Methodology not reported ($n$ = 30)[1] | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Economic assessment reported ($n$ = 29)[2] | | Economic assessment not reported ($n$ = 54)[2] | | Economic assessment reported ($n$ = 21)[2] | | Economic assessment not reported ($n$ = 9)[2] | | |
| | Statistically evaluated[3] | Not statistically evaluated[3] | Statistically evaluated[3] | Not statistically evaluated[3] | Statistically evaluated[3] | Not statistically evaluated[3] | Statistically evaluated[3] | Not statistically evaluated[3] | |
| Yes | 9 | 14 | 26 | 17 | 0 | 16 | 2 | 7 | 91 |
| No | 1 | 5 | 7 | 4 | 5 | 0 | 0 | 0 | 22 |
| Total | 10 | 19 | 33 | 21 | 5 | 16 | 2 | 7 | |

[1]If the methodology used for the economic/financial assessment was reported for the trial.
[2]If the type of economic assessment was reported.
[3]Whether the economic/financial difference between treatment was evaluated using a statistical model.

**Table 6.** The number of trials for each type of economic assessment by the reported methodology

| Economic/financial outcome reported as an outcome of interest? | Economic/financial assessment methodology reported? | Authors reported the type of economic assessment?[1] | Partial Budget | Cost/Relative Cost-effectiveness | Enterprise analysis | Cost-benefit | Not enough info. | Break-even analysis | Profitability | Other | Total (%)[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yes | Yes | No | 31 | 0 | 10 | 0 | 2 | 0 | 0 | 0 | 43 (38.1) |
| Yes | Yes | Yes | 4 | 3 | 4 | 4 | 0 | 3 | 3 | 2[3] | 23 (20.3) |
| Yes | No | Yes | 1 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 16 (14.2) |
| No | Yes | No | 8 | 0 | 0 | 0 | 2 | 0 | 0 | 1[4] | 11 (9.7) |
| Yes | No | No | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 9 (8.0) |
| No | Yes | Yes | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 6 (5.3) |
| No | No | Yes | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 (4.4) |
| No | No | No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (0.0) |
| | | Total (%)[2] | 52 (46.0) | 25 (22.1) | 14 (12.4) | 8 (7.1) | 5 (4.4) | 3 (2.7) | 3 (2.7) | 3 (2.7) | 113 (100) |

[1]If the type of economic assessment was not reported by the authors it was categorized by reviewers with content knowledge.
[2]Percentages are out of the total number of trials 113.
[3]Decision analysis and economic advantage
[4]Gross margin analysis

**Table 7.** The number of trials by economic assessment, intervention, measured animal outcomes, and outcome utilization and reporting

| Economic assessment (Citations) | Intervention | All animal outcomes measured | Animal outcomes utilized[2] | Primary?[3] | *N* |
|---|---|---|---|---|---|
| Break-even analysis[1] (*n* = 3) | | | | | |
| (Peterson et al., 1989; Lewis et al., 1990) | Feeding (*n* = 2) | Carcass, Live perf. | All | - | 1 |
| | | Live perf. | All | - | 1 |
| | Management (*n* = 1) | Live perf. | All | - | 1 |
| Cost–benefit analysis[1] (*n* = 8) | | | | | |
| (Kadel et al., 1985; Bechtol et al., 1991; Soll et al., 1991; Xiong et al., 1991; Blaine and Nsahlai, 2011; Van Donkersgoed et al., 2013; Van Donkersgoed and Hendrick, 2013) | Feeding (*n* = 1) | Carcass, Live perf. | Some | NR | 1 |
| | Management (*n* = 2) | Carcass, Live perf. | Some | NR | 1 |
| | | Health, Live perf. | Some | NR | 1 |
| | Parasite control (*n* = 1) | Carcass | All | - | 1 |
| | Parenteral antimicrobial (*n* = 2) | Health | None | - | 2 |
| | Vaccination (*n* = 2) | Health | All | - | 2 |
| Cost-effectiveness/Relative cost-effectiveness[1] (*n* = 25) | | | | | |
| (Bauck et al., 1989; Jim et al., 1999; Guichon et al., 2000; Schunicht et al., 2000; Schunicht et al., 2002a; Schunicht et al., 2002b; Schunicht et al., 2003; Booker et al., 2006; Booker et al., 2007; Schunicht et al., 2007;Perrett et al., 2008a; Perrett et al., 2008b; Perrett et al., 2008c; Van Donkersgoed et al., 2008a; Van Donkersgoed et al., 2008b; Wildman et al., 2008; Hannon et al., 2009; Wildman et al.,2009; Abutarbush et al., 2012; Van Donkersgoed and Merrill, 2012; Van Donkersgoed and Merrill, 2013a; Van Donkersgoed and Merrill, 2013b; Tennant et al., 2014; Van Donkersgoed et al., 2017) | Feeding (*n* = 1) | Carcass, Health, Live perf. | Significant only | NR | 1 |
| | Parasite control (*n* = 3) | Carcass, Health, Live perf. | Significant only | NR | 1 |
| | | Health, Live perf. | Some | Yes | 1 |
| | | Live perf. | All | - | 1 |
| | Parenteral antimicrobial (*n* = 17) | Carcass, Health, Live perf. | All | - | 1 |
| | | | Significant only | No | 1 |
| | | | | NR | 2 |
| | | | | Yes | 3 |
| | | Health | Significant only | NR | 1 |
| | | | | Yes | 1 |
| | | Health, Live perf. | Significant only | No | 1 |
| | | | | NR | 1 |
| | | | | Yes | 6 |
| | Vaccination (*n* = 4) | Carcass, Health, Live perf. | Significant only | NR | 4 |
| Decision analysis[1](*n* = 1) | | | | | |
| (Booker et al., 1992) | Parenteral antimicrobial (*n* = 1) | Health | All | - | 1 |
| Economic advantage[1] (*n* = 1) | | | | | |
| (Edwards and Laudert, 1984) | Management (*n* = 1) | Carcass, Health, Live perf. | Some | NR | 1 |
| Enterprise analysis (*n* = 14) | | | | | |
| (Hinman et al., 1999; Sawyer et al., 2004; Anderson et al., 2005; DeRouen and Foster, 2006; Bedwell et al., 2008; Kirkpatrick et al., 2008; McCartney et al., 2008; Mulliniks et al., 2012; Parish et al., 2013; Şentürklü et al., 2018) | Feeding (*n* = 9) | Carcass, Health | Some | NR | 3 |
| | | Carcass, Live perf. | All | - | 2 |
| | | Carcass, Live perf. | Some | NR | 1 |
| | | Carcass, Health, Live perf. | All | - | 3 |
| | Management (*n* = 3) | Carcass, Live perf. | All | - | 3 |
| | Multiple (*n* = 1) | Carcass, Health, Live perf. | All | - | 1 |
| | Vaccination (*n* = 1) | Carcass, Health, Live perf. | Some | NR | 1 |
| Gross Margin analysis (*n* = 1) | | | | | |
| (Lefebvre et al., 2006) | Multiple (*n* = 1) | Carcass, Live perf. | Some | NR | 1 |
| Not Enough Information (*n* = 5) | | | | | |
| (Williams et al., 1991; Loerch and Fluharty, 1998; Flatt et al., 2003; MacGregor and Wray, 2004; Mir et al., 2008) | Feeding (*n* = 3) | Carcass | Some | Yes | 1 |
| | | Carcass, Live perf. | Some | NR | 1 |
| | | Carcass, Health, Live perf. | Some | NR | 1 |
| | Parasite Control (*n* = 1) | Health, Live Perf. | Not reported | - | 1 |
| | Vaccination (*n* = 1) | Carcass, Health, Liveperf. | Some | NR | 1 |

**Table 7.** Continued

| Economic assessment (Citations) | Intervention | All animal outcomes measured | Animal outcomes utilized[2] | Primary?[3] | *N* |
|---|---|---|---|---|---|
| Partial Budget (*n* = 52) | | | | | |
| (Flack et al., 1967; Alexander and Miller, 1972; Price et al., 1978; Leland et al., 1980; Wellington and Van Schalkwyk, 1982; Campbell et al., 1987; Grimson et al., 1987; Karren et al., 1987; Louis et al., 1988; Mechor et al., 1988; Stanton et al., 1989; Jim et al., 1992; Bartle et al., 1994; Gallo and Berg, 1995; Dubeski et al., 1997; Jim et al., 1999; Gummow and Mapham 2000; MacGregor et al., 2001; Macken et al., 2003;Sawyer et al., 2003;Berthiaume, 2006;Stalker et al., 2006;McEwen et al., 2007; Shike et al., 2007; Vázquez-Añón et al., 2007; Bryant et al., 2008; Elam et al., 2008; Step et al., 2008;Larson et al., 2009;Sides et al., 2009; Cooprider et al., 2011; Van Donkersgoed et al., 2011; Swyers et al., 2014; Van Donkersgoed et al., 2014; Kononoff et al., 2015; Rogers et al., 2015; Forte et al., 2018; Rivera et al., 2018) | Feeding (*n* = 16) | Live perf. | None | - | 1 |
| | | Carcass, Live perf. | All | - | 3 |
| | | | Some | NR | 2 |
| | | | Significant only | NR | 1 |
| | | | Not reported | - | 1 |
| | | Health, Live perf. | All | - | 1 |
| | | | Some | - | 2 |
| | | Carcass, Health, Live perf. | Some | NR | 4 |
| | | | Significant only | NR | 1 |
| | Management (*n* = 9) | Carcass, Live perf. | All | - | 2 |
| | | | Some | NR | 2 |
| | | Carcass, Health, Live perf. | All | - | 1 |
| | | | Some | NR | 2 |
| | | Health, Live perf. | All | - | 2 |
| | Multiple (*n* = 6) | Carcass, Live perf. | All | - | 3 |
| | | | Some | NR | 3 |
| | Parasite Control (*n* = 16) | Carcass, Health | Some | NR | 1 |
| | | Carcass, Health, Live perf. | Some | Yes | 1 |
| | | | Significant only | NR | 1 |
| | | Health, Live perf. | All | - | 6 |
| | | Live perf. | All | - | 7 |
| | Parenteral antimicrobial (*n* = 2) | Health | Some | Yes | 2 |
| | Vaccination (*n* = 3) | Carcass, Health | All | - | 1 |
| | | Carcass, Health, Live perf. | All | - | 1 |
| | | | Some | NR | 1 |
| Profitability[1] (*n* = 3) | | | | | |
| (Stegner et al., 2013; Gillespie-Lewis et al., 2016) | Feeding (*n* = 2) | Carcass, Live perf. | All | - | 2 |
| | Parenteral antimicrobial (*n* = 1) | Carcass, Health, Live perf. | Not reported | - | 1 |

Live perf. = Live performance; NR = Not reported.
[1]Includes only author reported types of economic assessment.
[2]Which of the measured animal outcomes were used to derive the cost/benefit of the intervention.
[3]If the animal outcomes used to determine the cost/benefit of the intervention were included in the authors' stated primary objectives. Only "significant only" or "some" animal outcome utilized were extracted. If the authors did not report their primary objective(s), it was extracted as "not reported."

cost-effectiveness/relative cost-effectiveness. In several of the reported cost-effectiveness/relative cost-effectiveness studies, the authors used monetary units to quantify costs and outcomes (i.e., a cost–benefit analysis), where a cost-effectiveness analysis would use an appropriate natural nonmonetary effect (Babo Martins and Rushton, 2014). It was beyond the scope of this review to confirm whether the methods employed and type of assessment reported conformed to conventional use of these terms in the economic literature; however, after a brief perusal of this information, we found discrepancies in the use of the terminology employed to characterize economic assessments.

After evaluating the methods from trials without a specific economic assessment reported, we identified three types that were used: partial budget (*n* = 47), enterprise analysis (*n* = 10), and gross margin analysis (*n* = 1). There was not enough information provided in the article to determine the type of economic assessment used in five trials. The type of economic assessment by the reporting of the economic/financial outcome and methodology is presented in Table 6. Some studies lacked descriptions or had incomplete descriptions of economic data, including not reporting economic values and not identifying the data source, which created difficulties for identifying the type of assessment used. In addition, the classification of the type of economic assessment for these studies may be biased as it was conducted, though by a context expert (i.e., agricultural economist), via a sole reviewer.

The types of economic assessments used by intervention, measured animal outcome, and outcome utilization are presented in Table 7. All measured outcomes were used to

estimate the economic/financial consequences of the intervention in 42% (47/113) of the trials and two types of economic assessment were primarily used, partial budget (27/47) and enterprise budget analysis (9/47); more than one type of animal outcome was measured in 72% (34/47) of these trials. Only some of the measured animal outcomes were analyzed in 31% (35/113) of the trials and a partial budget analysis was the most common economic assessment (57%; 20/35). In only 14% (5/35) of these trials the measured animal outcome(s) used in the economic/financial analysis was reported as primary outcome(s). The outcomes of primary interest were not stated in the other 86% (30/35) of these trials. As with any study, identifying the primary outcome(s) and utilizing an appropriate sample size are crucial for accurately and precisely estimating the magnitude of the effects between interventions and outcomes (Sargeant et al., 2010), and economic analyses are no different. Stating if the economic/financial outcome is a primary or secondary objective of the study would allow the researchers to ensure that the study would be appropriately sized for accurate estimation and proper inference.

In three trials, only the cost of the intervention, but no health, performance, or carcass outcomes, was reported; a cost–benefit analysis was performed in two of these trials and the investigators a priori planned to utilize only significant outcomes in the analysis (although none were significant) (Table 7). The outcomes used to estimate the cost and benefits of the intervention were not reported in three of the trials (Table 7). Only animal outcomes that were significantly different between treatments were analyzed in 22% (25/113) of the trials and a cost-effectiveness or relative cost-effectiveness analysis was performed for 88% (22/25) of these trials (Table 7). The significantly different animal outcomes used in the economic/financial analysis were stated as primary objectives in 40% (10/25) of these trials, in 8% (2/25) the animal outcomes used were not the primary outcomes of interest, and in 52% (13/25) of the trials the outcomes of primary interest were not stated (Table 7). Utilizing a subset of the results to calculate the economic benefit and/or cost of the intervention may lead to an over or under-estimation of the value in part due to type I and type II errors incurred when analyzing multiple outcomes before performing the economic assessment.

All or some of the values used to estimate the economic/financial outcome were reported in 86% (97/113) of the trials. The sources for all or some of the values used to estimate the economic/financial outcome were reported in 57% (64/113) of the trials. Only private sources were cited in 55% (35/64) of these trials, both private and public sources were cited in 28% (18/64), only public sources were cited in 11% (7/64), public sources and commercial services were cited in 5% (3/64), and only commercial services were cited in a single trial (2%). The date of the study or the date the values were sourced was reported in 39% (44/113) of the trials (Table 8). While it is understandable that detailed financial information from commercial feedlots may not be publicly available, baseline data on values utilized in calculations are necessary for researchers to assess validity and reproducibility (Sargeant et al., 2010).

An economic/financial outcome stated as an outcome of interest, the methodology used and/or the type of method, and the values, sources, and dates of some or all of the information used in the economic/financial assessment were reported in 28% of the trials (32/113; Table 8). When considering trials where the methodology and supporting information were reported, but the economic/financial outcome was not stated as an outcome of interest (5/113; Table 8), only about a third of the trials met the minimum requirements needed to reproduce the trial results as they pertain to the economic/financial assessment. Not reporting the values used in the economic assessments and their sources limits the inference and external validity of the study and creates a barrier to reproducibility. In other words, lack of reporting limits the value of the publication for end-users (Sargeant et al., 2010). In addition, the increase in the sheer number of studies being published necessitates the use of knowledge synthesis tools, such as scoping reviews, systematic reviews, and meta-analyses, for proper contextualization of the evidence from studies and without thorough reporting, the ability to use these tools is hampered (Page et al., 2021). Given the importance of economic outcomes on the management of livestock production

**Table 8.** The number of trials, percentages, and types of sources grouped by the reporting of the economic data used in the economic/financial assessment by different types of methodology reporting

| Economic/financial outcome stated as an outcome of interest? | Economic/financial assessment methodology reported? | Type of Economic assessment reported? | Value, Source and Date[1] | Value and Source[1] | Source and Date[1] | Value and Date | Value | Source[1] | No info. | Total (%)[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *N* | | | | |
| Yes | Yes | Yes | 15(A) | 1(PP) | 1 (PR) | 0 | 4 | 0 | 2 | 23 (20.3) |
| Yes | Yes | No | 15(A) | 17(PP) | 3 (PR) | 0 | 6 | 1 (PR) | 1 | 43 (38.0) |
| Yes | No | Yes | 2(PR) | 0 | 0 | 0 | 14 | 0 | 0 | 16 (14.2) |
| Yes | No | No | 0 | 1 (PR) | 1 (PR) | 0 | 1 | 0 | 6 | 9 (8.0) |
| No | Yes | Yes | 2(PP) | 0 | 1(PR) | 1 | 2 | 0 | 0 | 6 (5.3) |
| No | Yes | No | 3(PP) | 1 (PR) | 0 | 0 | 7 | 0 | 0 | 11 (9.7) |
| No | No | Yes | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 5 (4.4) |
| No | No | No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (0.0) |
| | | Total (%)[2] | 37 (32.7) | 20 (17.7) | 6 (5.3) | 1 (0.9) | 39 (34.5) | 1 (0.9) | 9 (7.1) | 113 (100) |

[1]Acronyms in parentheses indicate the types of sources utilized: A, all: private, public and/or commercial services; CS, commercial service; PP, private and/or public; PR, private; PU, public.
[2]Percentages are out of the total number of trials 113.

systems, further work is warranted on creating guidelines or standards of practice to improve reporting of economic assessments from livestock field trials.

## SUPPLEMENTARY DATA

Supplementary data are available at *Translational Animal Science* online.

## ACKNOWLEDGMENTS

This work was funded by the College of Veterinary Medicine at Kansas State University and Merck Animal Health. The funders had no role in the design or implementation of the study. The authors thank Roberta Hodges and Monica Anderson for their assistance with retrieving and managing journal articles.

## Conflict of interest statement

The authors declare no conflict of interest.

## LITERATURE CITED

Abutarbush, S. M., O. C. Schunicht, B. K. Wildman, S. J. Hannon, G. K. Jim, T. I. Ward, and C. W. Booker. 2012. Comparison of enrofloxacin and ceftiofur sodium for the treatment of relapse of undifferentiated fever/bovine respiratory disease in feedlot cattle. *Can. Vet. J.* 53:57–62. PMID: 22753964.

Alexander, J. R., and R. F. Miller. 1972. Economic evaluation of anthelmintics under commercial feedlot conditions. *Vet. Med. Small Anim. Clin.* 67:1142–1146. PMID: 4562775.

Anderson, R. V., R. J. Rasby, T. J. Klopfenstein, and R. T. Clark. 2005. An evaluation of production and economic efficiency of two beef systems from calving to slaughter. *J. Anim. Sci.* 83:694–704. doi:10.2527/2005.833694x

Arksey, H., and L. O'Malley. 2005. Scoping studies: towards a methodological framework. *Int. J. Soc. Res. Methodol.* 8:19–32. doi:10.1080/1364557032000119616

Australian Lot Feeders Association. n.d. Industry Overview. Accessed May 18, 2022. https://www.feedlots.com.au/overview.

Babo Martins, S., and J. Rushton. 2014. Cost-effectiveness analysis: adding value to assessment of animal health, welfare and production. *Rev. Sci. Tech. Off. Int. Epiz.* 33:681–689. doi:10.20506/rst.33.3.2312

Bartle, S. J., R. L. Preston, and M. F. Miller. 1994. Dietary energy source and density: effects of roughage source, roughage equivalent, tallow level, and steer type on feedlot performance and carcass characteristics. *J. Anim. Sci.* 72:1943–1953. doi:10.2527/1994.7281943x

Bauck, S. W., G. K. Jim, P. T. Guichon, K. M. Newcomb, J. L. Cox, and R. Barrick. 1989. Comparative cost-effectiveness of ivermectin versus topical organophosphate in feedlot calves. *Can. Vet. J.* 30:161–164. PMID: 17423237.

Bechtol, D. T., R. T. Ballinger, and A. J. Sharp. 1991. Field trial of *Pasteurella haemolytica* toxoid administered at spring branding and in the feedlot. *Agri-Pract.* 12:6–14.

Bedwell, P. S., D. B. Faulkner, D. W. Shike, D. F. Parrett, L. L. Berger, F. A. Ireland, and T. G. Nash. 2008. Effects of source of energy on performance, ultrasonic, carcass, and economic characteristics of early-weaned heifers. *Prof. Anim. Sci.* 24:451–459. doi:10.15232/S1080-7446(15)30878-0

Berthiaume, R., I. Mandell, L. Faucitano, and C. Lafrenière. 2006. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 1. Feedlot performance, carcass quality, and production costs. *J. Anim. Sci.* 84:2168–2177. doi:10.2527/jas.2005-328.

Blaine, K. L., and I. V. Nsahlai. 2011. The effects of shade on performance, carcass classes and behaviour of heat-stressed feedlot cattle at the finisher phase. *Trop. Anim. Health Prod.* 43:609–615. doi:10.1007/s11250-010-9740-x

Booker, C. W., S. M. Abutarbush, B. K. Wildman, P. T. Guichon, T. J. Pittman, C. Jones, and C. M. Pollock. 2007. Evaluation of the efficacy of tulathromycin as a metaphylactic antimicrobial in feedlot calves. *Vet. Ther.* 8:18. PMID: 17926304.

Booker, C. W., G. K. Jim, and P. T. Guichon. 1992. A field trial to determine the efficacy of long-acting oxytetracycline for reducing the treatment rate in aborted feedlot heifers. *Can. Vet. J.* 33:397–399. PMID: 17424022.

Booker, C. W., O. C. Schunicht, P. T. Guichon, G. K. Jim, B. K. Wildman, T. J. Pittman, and T. Perrett. 2006. An evaluation of the metaphylactic effect of ceftiofur crystalline free acid in feedlot calves. *Vet. Ther.* 7:257–274. PMID: 17039449.

Bryant, T. C., K. C. Rogers, N. D. Stone, and D. G. Miles. 2008. Effect of viral respiratory vaccine treatment on performance, health and carcass traits of auction-origin feeder steers. *Bov. Pract.* 42:96–103. doi:10.21423/bovine-vol42no1p98-103

Campbell, J. B., I. L. Berry, D. J. Boxler, R. L. Davis, D. C. Clanton, and G. H. Deutscher. 1987. Effects of Stable Flies (Diptera: Muscidae) on weight gain and feed efficiency of feedlot cattle. *J. Econ. Entomol.* 80:117–119. doi:10.1093/jee/80.1.117

Cooprider, K. L., F. M. Mitloehner, T. R. Famula, E. Kebreab, Y. Zhao, and A. L. Van Eenennaam. 2011. Feedlot efficiency implications on greenhouse gas emissions and sustainability. *J. Anim. Sci.* 89:2643–2656. doi:10.2527/jas.2010-3539

DeRouen, S. M., and D. H. Foster. 2006. Effects of feeding broiler litter-based diets on live animal performance and economics with cull beef cows. *Prof. Anim. Sci.* 22:334–340. doi:10.15232/S1080-7446(15)31116-5

Dubeski, P. L., J. L. Aalhus, S. D. M. Jones, A. K. W. Tong, and W. M. Robertson. 1997. Fattening heifers to heavy weights to enhance marbling: Efficiency of gain. *Can. J. Anim. Sci.* 77:625–633. doi:10.4141/a96-050

Edwards, A. J., and S. B. Laudert. 1984. Economic evaluation of the use of feedlot abortifacients. *Bov. Pract.* 19:148–150. doi:10.21423/BOVINE-VOL1984NO19P148-150

Elam, N. A., D. U. Thomson, and J. F. Gleghorn. 2008. Effects of long- or short-term exposure to a calf identified as persistently infected with bovine viral diarrhea virus on feedlot performance of freshly weaned, transport-stressed beef heifers. *J. Anim. Sci.* 86:1917–1924. doi:10.2527/jas.2007-0535

Environmental Protection Agency. n.d. Animal Feeding Operations (AFOs). Accessed June 01, 2020. https://www.epa.gov/npdes/animal-feeding-operations-afos.

Flack, D. E., B. N. Frank, H. L. Easterbrooks, and G. E. Brown. 1967. Thiabendazole treatment. Effect upon weight gains, feed efficiency and cost of gain in commercial feedlot cattle. *Vet. Med. Small Anim. Clin.* 62:565–568.

Flatt, W. R., T. L. Stanton, D. Schutz, J. Davis, and T. E. Engle. 2003. Case Study: Effects of salt level on growth performance, carcass characteristics, and manure salinity of finishing beef steers. *Prof. Anim. Sci.* 19:239–243. doi:10.15232/S1080-7446(15)31411-X

Forte, E. M., M. K. Mullenix, J. J. Tucker, J. B. Elmore, and W. G. Bergen. 2018. Conserved forage-based systems for backgrounding weaned beef calves. *Transl. Anim. Sci.* 2:272–279. doi:10.1093/tas/txy063

Gallo, G. F., and J. L. Berg. 1995. Efficacy of a feed-additive antibacterial combination for improving feedlot cattle performance and health. *Can. Vet. J.* 36:223–229. PMID: 7600512.

Gillespie-Lewis, K. L., B. L. Nuttelman, J. D. Volesky, G. E. Erickson, T. J. Klopfenstein, J. C. MacDonald, and A. K. Watson. 2016. Case Study: Distillers grains supplementation in a forage system with spayed heifers. *Prof. Anim. Sci.* 32:357–367. doi:10.15232/pas.2015-01452

Grimson, R. E., R. P. Stilborn, P. K. Gummeson, W. H. D. Leaning, J. Guerrero, and K. M. Newcomb. 1987. Effect of antiparasitic

treatments on performance and profitability. *Mod. Vet. Pract.* 68:361–364.

Grindlay, D. J., M. L. Brennan, and R. S. Dean. 2012. Searching the veterinary literature: a comparison of the coverage of veterinary journals by nine bibliographic databases. *J. Vet. Med. Educ.* 39:404–412. doi:10.3138/jvme.1111.109R

Guichon, P. T., G. K. Jim, C. W. Booker, O. C. Schunicht, B. K. Wildman, and J. R. Brown. 2000. Relative cost-effectiveness of treatment of feedlot calves with ivermectin versus treatment with a combination of fenbendazole, permethrin, and fenthion. *J. Am. Vet. Med. Assoc.* 216:1965–1969. doi:10.2460/javma.2000.216.1965

Gummow, B., and P. H. Mapham. 2000. A stochastic partial-budget analysis of an experimental *Pasteurella haemolytica* feedlot vaccine trial. *Prev. Vet. Med.* 43:29–42. doi:10.1016/s0167-5877(99)00071-9

Hannon, S. J., T. Perrett, B. K. Wildman, O. C. Schunicht, A. R. Vogstad, R. K. Fenton, L. O. Burciaga-Robles, C. M. Pollock, G. K. Jim, J. Berg, et al. 2009. Efficacy of a florfenicol–flunixin meglumine combination product versus tulathromycin or ceftiofur crystalline free acid for the treatment of undifferentiated fever in feedlot calves. *Vet. Ther.* 10:E1–E18. PMID: 20425733.

Hinman, D. D., S. J. Sorensen, P. A. Momont, and L. Spiece. 1999. Canola meal compared with urea in a barley and potato processing residue finishing diet for feedlot steers. *Prof. Anim. Sci.* 15:191–195. doi:10.15232/S1080-7446(15)31757-5

Husereau, D., M. Drummond, S. Petrou, C. Carswell, D. Moher, D. Greenberg, F. Augustovski, A. H. Briggs, J. Mauskopf, and E. Loder. 2013. Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluation Publication Guidelines Good Reporting Practices Task Force. *Value Health* 16:231–250. doi:10.1016/j.jval.2013.02.002

Jim, G. K., C. W. Booker, and P. T. Guichon. 1992. A comparison of trimethoprim-sulfadoxine and ceftiofur sodium for the treatment of respiratory disease in feedlot calves. *Can. Vet. J.* 33:245–250. PMID: 17423983.

Jim, G. K., C. W. Booker, P. T. Guichon, O. C. Schunicht, B. K. Wildman, J. C. Johnson, and P. W. Lockwood. 1999. A comparison of florfenicol and tilmicosin for the treatment of undifferentiated fever in feedlot calves in western Canada. *Can. Vet. J.* 40:179–184. PMID: 10086218.

Jim, G. K., C. S. Ribble, P. T. Guichon, and B. E. Thorlakson. 1991. The relative economics of feeding open, aborted, and pregnant feedlot heifers. *Can. Vet. J.* 32:613–617. PMID: 17423875.

Kadel, W. L., M. M. Chengappa, and C. E. Herren. 1985. Field-trial evaluation of a *Pasteurella* vaccine in preconditioned and nonpreconditioned lightweight calves. *Am. J. Vet. Res.* 46:1944–1948. PMID: 4051299.

Karren, D. B., J. A. Basarab, and T. L. Church. 1987. The growth and economic performance of preconditioned calves and their dams on the farm and of calves in the feedlot. *Can. J. Anim. Sci.* 67:327–336. doi:10.4141/cjas87-031

Kirkpatrick, J. G., D. L. Step, M. E. Payton, J. B. Richards, L. F. McTague, J. T. Saliki, A. W. Confer, B. J. Cook, S. H. Ingram, and J. C. Wright. 2008. Effect of age at the time of vaccination on antibody titers and feedlot performance in beef calves. *J. Am. Vet. Med. Assoc.* 233:136–142. doi:10.2460/javma.233.1.136

Kononoff, P. J., P. J. Defoor, M. J. Engler, R. S. Swingle, S. T. James, H. M. Deobald, J. L. Deobald, G. N. Woronuk, and F. L. S. Marquess. 2015. Performance and carcass characteristics when sorting feedlot cattle on the basis of phenotype, and leptin genotype along with differential use of β-adrenergic agonists. *Can. J. Anim. Sci.* 95:455–463. doi:10.4141/cjas-2014-052

Larson, D. M., J. L. Martin, D. C. Adams, and R. N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. *J. Anim. Sci.* 87:1147–1155. doi:10.2527/jas.2008-1323

Lefebvre, B., F. Malouin, G. Roy, K. Giguère, and M. S. Diarra. 2006. Growth performance and shedding of some pathogenic bacteria in feedlot cattle treated with different growth-promoting agents. *J. Food Prot.* 69:1256–1264. doi:10.4315/0362-028X-69.6.1256

Leland, E., V. Davis, H. K. Caley, D. W. Arnett, and R. K. Ridley. 1980. Economic value and course of infection after treatment of cattle having a low level of nematode parasitism. *Am. J. Vet. Res.* 41:623–633. PMID: 6447467.

Levac, D., H. Colquhoun, and K. K. O'Brien. 2010. Scoping studies: advancing the methodology. *Implement. Sci.* 5:69. doi:10.1186/1748-5908-5-69

Lewis, J. M., T. J. Klopfenstein, G. A. Pfeiffer, and R. A. Stock. 1990. An economic evaluation of the differences between intensive and extensive beef production systems. *J. Anim. Sci.* 68:2506–2516. doi:10.2527/1990.6882506x

Loerch, S. C., and F. L. Fluharty. 1998. Effects of programming intake on performance and carcass characteristics of feedlot cattle. *J. Anim. Sci.* 76:371–377. doi:10.2527/1998.762371x

Louis, S. L., A. Sidik, G. E. Cooper, and S. Gelaye. 1988. A comparison of corn and sweet potato meal in finishing rations for beef steers. *Nutr. Rep. Int.* 38:463–475.

MacGregor, D. S., D. R. Yoder, and R. S. Rew. 2001. Impact of doramectin treatment at the time of feedlot entry on the productivity of yearling steers with natural nematode infections. *Am. J. Vet. Res.* 62:622–624. doi:10.2460/ajvr.2001.62.622

MacGregor, S., and M. I. Wray. 2004. The effect of bovine respiratory syncytial virus vaccination on health, feedlot performance and carcass characteristics of feeder cattle. *Bov. Pract.* 38:162–170. doi:10.21423/bovine-vol38no2p162-170

Macken, C. N., C. T. Milton, T. J. Klopfenstein, B. D. Dicke, and D. E. McClellan. 2003. Effects of final implant type and supplementation of melengestrol acetate on finishing feedlot heifer performance, carcass characteristics, and feeding economics. *Prof. Anim. Sci.* 19:159–170. doi:10.15232/S1080-7446(15)31395-4

McCartney, D. H., H. A. Lardner, and F. C. Stevenson. 2008. Economics of backgrounding calves on Italian ryegrass (*Lolium multiflorum*) pastures in the Aspen Parkland. *Can. J. Anim. Sci.* 88:19–28. doi:10.4141/cjas07064

McEwen, P. L., I. B. Mandell, G. Brien, and C. P. Campbell. 2007. Effects of grain source, silage level, and slaughter weight endpoint on growth performance, carcass characteristics, and meat quality in Angus and Charolais steers. *Can. J. Anim. Sci.* 87:167–180. doi:10.4141/a06-082

Mechor, G. D., G. K. Jim, and E. D. Janzen. 1988. Comparison of penicillin, oxytetracycline, and trimethoprim-sulfadoxine in the treatment of acute undifferentiated bovine respiratory disease. *Can. Vet. J.* 29:438–443. PMID: 17423045.

Millen, D. D., R. D. L. Pacheco, P. M. Meyer, P. H. M. Rodrigues, and M. D. B. Arrigoni. 2011. Current outlook and future perspectives of beef production in Brazil. *Anim. Front.* 1:46–52. doi:10.2527/af.2011-0017

Mir, P. S., K. S. Schwartzkopf-Genswein, T. Entz, K. K. Klein, E. Okine, and M. V. Dodson. 2008. Effect of a short duration feed withdrawal followed by full feeding on marbling fat in beef carcasses. *Livest. Sci.* 116:22–29. doi:10.1016/j.livsci.2007.08.015

Mulliniks, J. T., J. E. Sawyer, C. P. Mathis, S. H. Cox, and M. K. Petersen. 2012. Winter protein management during late gestation alters range cow and steer progeny performance. *J. Anim. Sci.* 90:5099–5106. doi:10.2527/jas.2012-5535

O'Connor, A. M., J. M. Sargeant, I. A. Gardner, J. S. Dickson, M. E. Torrence, C. E. Dewey, I. R. Dohoo, R. B. Evans, J. T. Gray, M. Greiner, et al.; . 2010. The REFLECT statement: methods and processes of creating reporting guidelines for randomized controlled trials for livestock and food safety. *J. Vet. Intern. Med.* 24:57–64. doi:10.1111/j.1939-1676.2009.0441.x

Page, M. J., J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, et al. 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 372:n71. doi:10.1136/bmj.n71

Parish, J. A., J. R. Parish, T. F. Best, H. T. Boland, and C. A. Young. 2013. Effects of selected endophyte and tall fescue cultivar combinations

on steer grazing performance, indicators of fescue toxicosis, feedlot performance, and carcass traits. *J. Anim. Sci.* 91:342–355. doi:10.2527/jas.2011-4725

Perrett, T., S. M. Abutarbush, R. K. Fenton, G. K. Jim, P. T. Guichon, C. W. Booker, J. Berg, J. Roder, and M. Spire. 2008a. A comparison of florfenicol and tulathromycin for the treatment of undifferentiated fever in feedlot calves. *Vet. Ther.* 9:128–140. PMID: 18597251.

Perrett, T., B. K. Wildman, S. M. Abutarbush, T. J. Pittman, C. Jones, C. M. Pollock, O. C. Schunicht, P. T. Guichon, G. K. Jim, and C. W. Booker. 2008c. A comparison of two *Mannheimia haemolytica* immunization programs in feedlot calves at high risk of developing undifferentiated fever/bovine respiratory disease. *Bov. Pract.* 42:64–75. doi:10.21423/bovine-vol42no1p64-75

Perrett, T., B. Wildman, G. Jim, A. Vogstad, R. Fenton, S. Hannon, O. Schunicht, S. Abutarbush, and C. Booker. 2008b. Evaluation of the efficacy and cost-effectiveness of melengestrol acetate in feedlot heifer calves in western Canada. *Vet. Ther.* 9:223–240. PMID: 19003783.

Peterson, E. B., D. R. Strohbehn, G. W. Ladd, and R. L. Willham. 1989. The economic viability of preconditioning for cow-calf producers. *J. Anim. Sci.* 67:1687–1697. doi:10.2527/jas1989.6771687x

Price, M. A., G. W. Mathison, and R. T. Berg. 1978. Effects of dietary roughage level on the feedlot performance and carcass characteristics of bulls and steers. *Can. J. Anim. Sci.* 58:303–311. doi:10.4141/cjas78-040

Rivera, J. D., J. T. Johnson, and G. K. Blue. 2018. Effects of oral tilmicosin on health and performance in newly received beef heifers. *Prof. Anim. Sci.* 34:42–50. doi:10.15232/pas.2017-01639

Rogers, K. C., D. G. Miles, H. D. Hughes, D. G. Renter, and S. Zuidhof. 2015. Effect of initial respiratory viral-bacterial combination vaccine on performance, health, and carcass traits of auction-market derived feedlot heifers. *Bov. Pract.* 49:43–47. doi:10.21423/bovine-vol49no1p43-47

Sanghera, S., E. Frew, T. Roberts, D. Husereay, M. Drummond, S. Petrou, D. Greenberg, J. Mauskopf, F. Augustovski, A. H. Briggs, et al. 2015. Adapting the CHEERS statement for reporting cost-benefit analysis/reply to Roberts *et al.*: CHEERS is sufficient for reporting cost-benefit analysis, but may require further elaboration. *PharmacoEcon.* 33:533–536. doi:10.1007/s40273-015-0265-z

Sargeant, J. M., A. M. O'Connor, I. A. Gardner, J. S. Dickson, M. E. Torrence, I. R. Dohoo, S. L. Lefebvre, P. S. Morley, A. Ramirez, and K. Snedeker. 2010. The REFLECT statement: reporting guidelines for randomized controlled trials in livestock and food safety: explanation and elaboration. *J. Food Prot.* 73:25. doi:10.4315/0362-028x-73.3.579

Sawyer, J. E., C. P. Mathis, and B. Davis. 2004. Effects of feeding strategy and age on live animal performance, carcass characteristics, and economics of short-term feeding programs for culled beef cows. *J. Anim. Sci.* 82:3646–3653. doi:10.2527/2004.82123646x

Sawyer, J. E., C. P. Mathis, C. A. Löest, D. A. Walker, K. J. Malcolm-Callis, L. A. Blan, and R. Taylor. 2003. Niche-targeted vs conventional finishing programs for beef steers. *Prof. Anim. Sci.* 19:188–194. doi:10.15232/S1080-7446(15)31398-X

Schunicht, O. C., C. W. Booker, P. T. Guichon, G. K. Jim, B. K. Wildman, B. W. Hill, T. I. Ward, and S. W. Bauck. 2002a. An evaluation of the relative efficacy of a new formulation of oxytetracycline for the treatment of undifferentiated fever in feedlot calves in western Canada. *Can. Vet. J.* 43:940–945. PMID: 12561688.

Schunicht, O. C., C. W. Booker, P. T. Guichon, G. K. Jim, B. K. Wildman, T. J. Pittman, and T. Perrett. 2007. An evaluation of the relative efficacy of tulathromycin for the treatment of undifferentiated fever in feedlot calves in Nebraska. *Can. Vet. J.* 48:600–606. PMID: 17616056.

Schunicht, O. C., C. W. Booker, G. K. Jim, P. T. Guichon, B. K. Wildman, and B. W. Hill. 2003. Comparison of a multivalent viral vaccine program versus a univalent viral vaccine program on animal health, feedlot performance, and carcass characteristics of feedlot calves. *Can. Vet. J.* 44:43–50. PMID: 12619555.

Schunicht, O. C., P. T. Guichon, C. W. Booker, G. K. Jim, B. K. Wildman, S. W. Bauck, and S. J. Gross. 2000. Comparative cost-effectiveness of ivermectin versus topical organophosphate in feedlot yearlings. *Can. Vet. J.* 41:220–224. PMID: 10738601.

Schunicht, O. C., P. T. Guichon, C. W. Booker, G. K. Jim, B. K. Wildman, B. W. Hill, T. I. Ward, S. W. Bauck, and J. A. Jacobsen. 2002b. A comparison of prophylactic efficacy of tilmicosin and a new formulation of oxytetracycline in feedlot calves. *Can. Vet. J.* 43:355–362. PMID: 12001501.

Şentürklü, S., D. G. Landblom, R. Maddock, T. Petry, C. J. Wachenheim, and S. I. Paisley. 2018. Effect of yearling steer sequence grazing of perennial and annual forages in an integrated crop and livestock system on grazing performance, delayed feedlot entry, finishing performance, carcass measurements, and systems economics. *J. Anim. Sci.* 96:2204–2218. doi:10.1093/jas/sky150

Shike, D. W., D. B. Faulkner, M. J. Cecava, D. F. Parrett, and F. A. Ireland. 2007. Effects of weaning age, creep feeding, and type of creep on steer performance, carcass traits, and economics. *Prof. Anim. Sci.* 23:325–332. doi:10.15232/S1080-7446(15)30985-2

Sides, G. E., J. T. Vasconcelos, R. C. Borg, O. A. Turgeon, W. C. Koers, M. S. Davis, K. Vander Pol, D. J. Weigel, and C. M. Tucker. 2009. A comparison of melengestrol acetate fed at two dose levels to feedlot heifers. *Prof. Anim. Sci.* 25:731–736. doi:10.15232/S1080-7446(15)30782-8

Soll, M. D., I. H. Carmichael, and R. A. Barrick. 1991. Ivermectin treatment of feedlot cattle for *Parafilaria bovicola*. *Prev. Vet. Med.* 10:251–256. doi:10.1016/0167-5877(91)90010-Y

South African Feedlot Association. n.d. Environment guidelines for beef cattle. Accessed May 18, 2022. https://safeedlot.co.za/wp-content/uploads/2019/02/Environmental-Guidelines-for-Beef-Cattle3.pdf.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. M. Feuz, and R. N. Funston. 2006. Effects of pre- and postpartum nutrition on reproduction in spring calving cows and calf feedlot performance. *J. Anim. Sci.* 84:2582–2589. doi:10.2527/jas.2005-640

Stanton, T. L., C. P. Birkelo, and P. Grover. 1989. Monensin, lasalocid, ionophore rotation and Synovex/MGA effects on finishing heifer performance. *Agri-Pract.* 10:33–36.

Statistics Canada. n.d. Table 32-10-0130-01 Number of cattle, by class and farm type (x 1,000). Accessed May 16, 2022. doi:10.25318/3210013001-eng

Stegner, J. E., M. J. Lucas, C. L. McLaughlin, M. S. Davis, G. R. Alaniz, D. J. Weigel, J. H. Pollreisz, C. M. Tucker, W. C. Koers, O. A. Turgeon, et al. 2013. Comparative effects of therapeutic programs on bovine respiratory disease, performance, carcass, and profitability of high-risk feedlot heifers. *Prof. Anim. Sci.* 29:208–218. doi:10.15232/S1080-7446(15)30226-6

Step, D. L., C. R. Krehbiel, H. A. DePra, J. J. Cranston, R. W. Fulton, J. G. Kirkpatrick, D. R. Gill, M. E. Payton, M. A. Montelongo, and A. W. Confer. 2008. Effects of commingling beef calves from different sources and weaning protocols during a forty-two-day receiving period on performance and bovine respiratory disease. *J. Anim. Sci.* 86:3146–3158. doi:10.2527/jas.2008-0883

Swyers, K. L., J. J. Wagner, K. L. Dorton, and S. L. Archibeque. 2014. Evaluation of *Saccharomyces cerevisiae* fermentation product as an alternative to monensin on growth performance, cost of gain, and carcass characteristics of heavy-weight yearling beef steers. *J. Anim. Sci.* 92:2538–2545. doi:10.2527/jas.2013-7559

Tennant, T. C., S. E. Ives, L. B. Harper, D. G. Renter, and T. E. Lawrence. 2014. Comparison of tulathromycin and tilmicosin on the prevalence and severity of bovine respiratory disease in feedlot cattle in association with feedlot performance, carcass characteristics, and economic factors. *J. Anim. Sci.* 92:5203–5213. doi:10.2527/jas.2014-7814

Totton, S. C., J. N. Cullen, J. M. Sargeant, and A. M. O'Connor. 2018. The reporting characteristics of bovine respiratory disease clinical intervention trials published prior to and following publication of the REFLECT statement. *Prev. Vet. Med.* 150:117–125. doi:10.1016/j.prevetmed.2017.12.015

Tricco, A. C., E. Lillie, W. Zarin, K. K. O'Brien, H. Colquhoun, D. Levac, D. Moher, M. D. J. Peters, T. Horsley, L. Weeks, et al. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. *Ann. Intern. Med*. 169:467–473. doi:10.7326/M18-0850

United States Department of Agriculture. n.d. Feedlot 2011 "Part IV: Health and Health Management on U.S. Feedlots with a Capacity of 1,000 or More Head". USDA–APHIS–VS–CEAH–NAHMS. Fort Collins, CO #638.0913. Accessed May 18, 2022. https://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot2011/Feed11_dr_PartIV_1.pdf.

Van Donkersgoed, J., J. Berg, and S. Hendrick. 2008a. Comparison of florfenicol and tulathromycin for the treatment of undifferentiated fever in Alberta feedlot calves. *Vet. Ther*. 9:275–281. PMID: 19177332.

Van Donkersgoed, J., J. Berg, G. Royan, J. Hutcheson, and M. Brown. 2014. Comparative effects of zilpaterol hydrochloride and ractopamine hydrochloride on growth performance, carcass characteristics, and longissimus tenderness of feedlot steers fed barley-based diets. *Prof. Anim. Sci*. 30:56–61. doi:10.15232/S1080-7446(15)30083-8

Van Donkersgoed, J., and S. Hendrick. 2013. Clinical efficacy of gamithromycin versus florfenicol for the treatment of undifferentiated fever in winter-placed feedlot calves. *Bov. Pract*. 47:152–158. doi:10.21423/bovine-vol47no2p152-158

Van Donkersgoed, J., S. Hendrick, and T. Nickel. 2017. Comparison of gamithromycin and tildipirosin for metaphylaxis treatment of winter-placed feedlot calves for control of bovine respiratory disease. *Bov. Pract*. 51:184–189. doi:10.21423/bovine-vol51no2p184-189

Van Donkersgoed, J., and J. K. Merrill. 2012. A comparison of tilmicosin to gamithromycin for on-arrival treatment of bovine respiratory disease in feeder steers. *Bov. Pract*. 46:46–51. doi:10.21423/bovine-vol46no1p46-51

Van Donkersgoed, J., and J. K. Merrill. 2013a. Efficacy of tilmicosin for on-arrival treatment of bovine respiratory disease in backgrounded winter-placed feedlot calves. *Bov. Pract*. 47:7–12. doi:10.21423/bovine-vol47no1p7-14

Van Donkersgoed, J., and J. K. Merrill. 2013b. Efficacy of tilmicosin and tildipirosin for on-arrival treatment of bovine respiratory disease in fall-placed feedlot calves in western Canada. *Bov. Pract*. 47:146–151. doi:10.21423/bovine-vol47no2p146-151

Van Donkersgoed, J., J. Merrill, and S. Hendrick. 2008b. Comparative efficacy of tilmicosin versus tulathromycin as a metaphylactic antimicrobial in feedlot calves at moderate risk for respiratory disease. *Vet. Ther*. 9:291–297. PMID: 19177334.

Van Donkersgoed, J., J. K. Merrill, and S. Hendrick. 2013. Comparison of tilmicosin and gamithromycin for treatment of undifferentiated fever in backgrounded winter-placed feedlot calves. *Bov. Pract*. 47:15–19. doi:10.21423/bovine-vol47no1p15-21

Van Donkersgoed, J., G. Royan, J. Berg, J. Hutcheson, and M. Brown. 2011. Comparative effects of zilpaterol hydrochloride and ractopamine hydrochloride on growth performance, carcass characteristics, and longissimus tenderness of feedlot heifers fed barley-based diets. *Prof. Anim. Sci*. 27:116–121. doi:10.15232/S1080-7446(15)30457-5

Vázquez-Añón, M., T. Peters, T. Hampton, J. McGrath, and B. Huedepohl. 2007. Case Study: Supplementation of chelated forms of zinc, copper, and manganese to feedlot cattle with access to drinking water with high sulfate concentration. *Prof. Anim. Sci*. 23:58–63. doi:10.1532/S1080-7446(15)30937-2

Wellington, A. C., and L. Van Schalkwyk. 1982. The effect of a single injection of nitroxynil at 20 mg/kg live mass in the treatment of *Parafilaria bovicola* infestations in cattle. *J. S. Afr. Vet. Assoc*. 53:91–94. PMID: 7120274.

Wildman, B. K., G. K. Jim, T. Perrett, O. C. Schunicht, S. J. Hannon, R. K. Fenton, S. M. Abutarbush, and C. W. Booker. 2009. A comparison of two multivalent viral vaccine programs in feedlot calves at high risk of developing undifferentiated fever/bovine respiratory disease. *Bov. Pract*. 43:130–139. doi:10.21423/bovine-vol43no2p130-139

Wildman, B. K., T. Perrett, S. M. Abutarbush, P. T. Guichon, T. J. Pittman, C. W. Booker, O. C. Schunicht, R. K. Fenton, and G. K. Jim. 2008. A comparison of 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease. *Can. Vet. J*. 49:463–472. PMID: 18512457.

Williams, J. C., D. T. Bechtol, L. C. Hollis, and R. C. Herschler. 1991. Effects of oxfendazole, levamisole, and ivermectin treatment on removal of inhibited *Ostertagia ostertagi* larvae and production parameters in feedlot steers. *Agri-Pract*. 12:14–20. doi:10.1016/0304-4017(94)00701-D

Xiong, Y., S. J. Bartle, and R. L. Preston. 1991. Density of steam-flaked sorghum grain, roughage level, and feeding regimen for feedlot steers. *J. Anim. Sci*. 69:1707–1718. doi:10.2527/1991.6941707x