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Michael P. Keane , Mark McGee , Edward G. O’Riordan ,
Alan K. Kelly , Bernadette Earley

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Highlights

- No difference in animal performance between concrete slatted floors and rubber mats.
- Using rubber mats as opposed to concrete slatted floors had no effect on lying duration or dirt scores.
- No difference in animal performance between concrete slatted floors and straw bedding.
- No effect of replacing concrete slatted floors with straw on lying duration or dirt scores.

ACCEPTED MANUSCRIPT

**Effect of floor type on performance, lying time and dirt scores of finishing beef
cattle: A meta-analysis**

Michael P. Keane^{a,b}, Mark McGee^c, Edward G. O’Riordan^d, Alan K. Kelly^b and
Bernadette Earley^{a*}

^aAnimal and Bioscience Research Department, Animal & Grassland Research and
Innovation Centre, Teagasc, Grange, Dunsany, Co. Meath, Ireland

^bSchool of Agriculture and Food Science, University College Dublin, Belfield, Dublin
4, Ireland

^cLivestock Systems Research Department, Animal & Grassland Research and
Innovation Centre, Teagasc, Grange, Dunsany, Co. Meath, Ireland

^dGrassland Research Systems Research Department, Animal & Grassland Research
and Innovation Centre, Teagasc, Grange, Dunsany, Co. Meath, Ireland

*Corresponding author Bernadette.earley@teagasc.ie

Phone number +353469061100

Abstract

Data from individual studies evaluating the effect of housing systems on performance, lying time and dirt scores of finishing beef cattle are conflicting. The objective of this study was to collate the data from previous animal housing studies and quantify, through meta-analysis, the effect of floor type on animal performance, lying time and dirt scores. From 38 peer-reviewed articles, published between 1969 and 2017, 18 were determined to be eligible for meta-analysis. Papers were included in the study if they contained information on the effect of floor surface on animal performance (average daily liveweight gain (ADG), feed conversion ratio (FCR) and carcass weight), lying behaviour or animal cleanliness. There was no difference ($P > 0.10$) in ADG, FCR or carcass weight between concrete slatted floors (CSF) and CSF overlaid with rubber mats (RM). Using RM had no effect ($P > 0.10$) on lying duration or dirt scores of cattle. There was no difference ($P > 0.10$) in the ADG, FCR, carcass weight, lying duration or cleanliness of cattle housed on CSF or straw bedding. It was concluded that using RM or straw instead of CSF had no effect on performance, lying time or dirt scores.

Keywords

Beef cattle, meta-analysis, performance, lying time, dirt scores

Introduction

Floor type has been identified as a critical factor regarding the welfare of housed beef cattle (EFSA, 2006a; 2006b; 2009; 2012; EU Welfare Quality® project, 2009),

yet there is currently no legislative directive outlining the requirements for good animal welfare during housing for finishing cattle. The majority of European beef production systems generally consist of a grazing season followed by a winter housing period (CIGR, 2004). In Ireland, the grazing season is generally eight months followed by a four month housing period, however the housing duration may be longer, depending on the management system used (Drennan and McGee, 2009). Irrespective of the system used, beef cattle will spend a significant proportion of their lifetime indoors; therefore, the housing system will influence their overall performance and welfare.

There are conflicting results in the literature regarding the effect of floor type on animal performance, lying time and cleanliness. Lowe *et al.* (2001) compared concrete slatted floors (CSF) with CSF overlaid with rubber mats (RM) and found no difference in average daily live weight gain (ADG) or carcass weight of cattle on both floor surfaces. In contrast, Keane *et al.* (2015) reported a greater ADG for cattle on CSF overlaid with RM than on CSF, but found no difference in carcass weight. Straw bedding is often perceived as a more suitable floor type, than CSF, for beef cattle (Wechsler, 2011). However, a number of studies have found no difference in performance of cattle accommodated on straw bedding or CSF (Lowe *et al.*, 2001; Hickey *et al.*, 2003; Gottardo *et al.*, 2003). With regard to lying behaviour, Gyax *et al.* (2007) and Rouha-Muelleder *et al.* (2012) reported no difference in lying duration between bulls housed on straw bedding, CSF or RM. However, Hickey *et al.* (2003) reported a longer lying duration for steers on straw compared to CSF, whereas Keane *et al.* (2017) reported the opposite result for heifers. Furthermore, there is evidence to suggest that CSF can cause more abnormal lying postures in cattle when compared to those on straw bedding (Absmanner *et al.*, 2009). Furthermore,

studies investigating animal cleanliness also provide contrasting results, with some studies showing that cattle housed on straw were cleaner than those on CSF (Lowe *et al.*, 2001; Hickey *et al.*, 2003), whereas others have reported the opposite (Gottardo *et al.*, 2003; Tessitore *et al.*, 2009; Keane *et al.*, 2017), despite frequent straw replenishment and pen cleaning.

Wechsler (2011) recommended that CSF should not be used for housing beef cattle and instead must be replaced with alternative floor types such as RM or straw. A change of this magnitude could have a significant negative impact on European beef production. Therefore the objective of this study was to determine, through the meta-analysis of existing published data, the effect of floor type on performance, lying time and dirt scores of finishing beef cattle.

2. Materials and methods

2.1 Data collection

Data regarding the effect of floor type on the performance, behaviour and cleanliness of finishing cattle were collected from peer-reviewed journals, books and conference proceedings published between 1969 and 2017. A search for information was performed using databases, including Commonwealth Agricultural Bureau (CAB), ScienceDirect (www.sciencedirect.com), PubMed (www.ncbi.nlm.nih.gov/pubmed), Agricola (agricola.nal.usda.gov), Web of Science (www.isiwebofknowledge.com) and Google Scholar (<http://scholar.google.com>). The keywords used to search each database were: floor type, beef cattle, rubber mats, concrete slats, straw bedding, welfare, cattle behaviour and cattle cleanliness. Studies were only included in the meta-analysis if they provided information on at least two different floor types. The data obtained from each study were tabulated in an electronic spread-sheet.

The primary animal performance-related variables used in the meta-analysis were ADG, feed conversion ratio (FCR) and carcass weight. If the study contained no information on either ADG or carcass weight, it was excluded from the final analysis, unless it contained information on lying time or animal cleanliness. The FCR was obtained by dividing the kilograms of dry matter intake (DMI) per day by the kilograms of live weight gained per day.

With regard to animal behaviour, data were gathered on lying behaviour, non-aggressive social behaviour (grooming, sniffing, and rubbing) and aggressive behaviour. However, there was large variation in the methods used, to monitor behaviour, between studies. Therefore, only lying behaviour was selected for inclusion in the analysis as it was the only behavioural response that was recorded in a consistent manner across studies. Information relevant to lying behaviour was only included if the results were expressed on a time basis, so that a percentage of time spent on lying each day could be calculated. Similarly, papers containing information on animal cleanliness were only included if the scores were expressed in percentage terms, or if it was possible to calculate them as a percentage. This facilitated the inclusion of papers which used different methods of assessing animal cleanliness. There are numerous other different variables that can be used to assess the effect that housing systems have on beef cattle welfare, including hoof lesions, skin lesions, tail-tip necrosis and immune biomarkers. However, due to an insufficient number of studies that assessed these variables or variation between studies in the methods used to measure them, they could not be included in the current meta-analysis.

A total of 18 papers were used in the meta-analysis. A full list of the papers including the floor type comparison and the variables that they contained are presented in Table 1.

2.2 Statistical analysis

All statistical analysis was performed using the Comprehensive Meta-Analysis statistical software (version 3, Biostat, Englewood, NJ). The effect size was calculated for each study separately. As studies were carried out in different locations, by different research groups over a number of years, it created a heterogeneous population of studies. Therefore, a random effects model was used to calculate the pooled effect size (Halasa *et al.*, 2009). To account for the variation among studies, a weighted meta-regression was conducted. Factors selected for inclusion in the model, as moderator variables, were breed, age, and sex. Furthermore, for comparisons that investigated two different floor types, the difference in space allowance per animal between floor types was included as a moderator variable but was excluded from the final model if it did not affect the overall effect size. The meta-analysis was carried out on each of the variables for each comparison separately. The effect sizes of individual studies were weighted by multiplying them by the inverse variance of the study; therefore, large studies would have more of an influence on the pooled effect size. A Forest plot was used to illustrate the calculated effect size per study as well as the overall pooled effect size in the last line of the plot. Data were considered statistically significant when $P < 0.05$. Publication bias was assessed using funnel plots, which indicate the potential for publication bias using a technique that relates effect size to study size (Thornton

and Lee, 2000). When publication bias was deemed to exist, the trim and fill method (Duval and Tweedie, 2000) was used to correct for the bias.

Results

Description of the data set

The two comparisons investigated in this meta-analysis were: CSF versus vs. RM and CSF vs. straw bedding. Only one study (Lowe *et al.*, 2001) examined rubber mats and straw, therefore, statistical analysis of this comparison could not be carried out.

Meta-Analysis Results

The results for the effect of floor type are presented in Tables 2 and 3. There was no difference ($P > 0.10$) in ADG, FCR or carcass weight between CSF and RM. Housing animals on CSF overlaid with RM instead of CSF had no effect ($P > 0.10$) on total lying duration or dirt scores. With regards to straw bedding, no difference was detected in ADG, FCR, carcass weight, lying duration or cleanliness of cattle housed on CSF or straw bedding.

Discussion

The meta-analysis of existing data allows for the integrated quantification of the effects of different housing systems on animal performance, lying time and cleanliness. There have been reviews carried out on this topic before (Ingvarsen and Andersen, 1993; Wechsler, 2011), however, this is the first study, to the authors' knowledge, that has used meta-analysis to determine the effect of floor type on performance, lying time and dirt scores of finishing beef cattle. Although general

conclusions on animal welfare cannot be drawn from the current meta-analysis, as it only contained data on lying time and dirt scores, the results may be used to guide further research and thus inform proposed changes (Wechsler, 2011) to the current production systems.

The results of the current meta-analysis are in contrast to the findings of the SCAHAW (2001) that using RM as an alternative flooring type to CSF improves the ADG of finishing cattle. Likewise, Wechsler (2011) reported no difference in ADG between cattle housed on CSF and RM. Wechsler (2011) recommended that CSF should be replaced with RM due to the positive effect they have on animal behaviour rather than performance. However, the results for lying time in the current meta-analysis revealed no difference between the two floor types. Furthermore, Wechsler (2011) stated that RM reduce the risk of leg lesions occurring. While leg or hoof lesions have not been investigated in the current study, previous research has shown that cattle on RM can develop more leg swellings (Graunke *et al.* 2011) and hoof lesions (Keane *et al.*, 2015; Earley *et al.*, 2015; 2017) compared to those on CSF. However, there is also evidence to suggest that RM have a beneficial effect on the presence of skin lesions of the carpal and tarsal joints when compared to CSF (Platz *et al.*, 2007; Graunke *et al.*, 2011). It must be noted that the variety of RM used in the meta-analysis differed between studies, and therefore it cannot be concluded that all types of RM will have the same effect on animal performance, lying time and dirt scores. Although Earley *et al.* (2017) has examined the physical properties of different mat varieties, it is an area that requires further research, particularly, as there are new varieties of RM entering the market on a regular basis. As was the case with RM, using straw bedding as an alternative floor type to CSF had no effect on, performance, lying time or dirt scores in the current meta-analysis,

which is in accord with the conclusions reached by Ingvarlsen and Andersen (1993) and Wechsler (2011). Furthermore, the absence of an effect on lying duration by housing cattle on straw instead of CSF concurs is consistent with the conclusion of Wechsler (2011). However, Wechsler (2011) did report longer individual lying bouts for cattle housed on CSF than those on straw which suggests that cattle on straw are able to transition between standing and lying more easily than those on CSF. Although animal welfare cannot be evaluated by observing lying behaviour alone, it is a useful contributor to the overall assessment of animal welfare.

The clean livestock policy, which was introduced in the EU in 2006, with the aim of reducing the risk of E. Coli O157 and other zoonotic pathogens contaminating meat, requires that animals presented for slaughter should be clean (EC, 2004). While the results of the current analysis show no difference in cleanliness between cattle housed on CSF and straw, there may be particular discrepancies between individual studies due to management factors such as stocking rate, type of straw, straw replenishment rates, frequency of farmyard manure removal and diet. Although the current results show no negative aspects of using straw as an alternative to CSF, other factors need to be taken into consideration such as added labour requirements for maintaining straw pens, cost and availability of straw and additional over ground storage areas for FYM, as EU law prohibits the application of FYM to farmland without a storage period beforehand (EC, 2010).

Conclusion

The results of the current meta-analysis provide a better understanding of how finishing beef cattle respond to their housing environment. Placing RM on CSF had no effect on performance, lying time or animal cleanliness, however further research

is required examining different RM types. The provision of straw bedding also had no effect on any of the variables examined, suggesting that CSF are adequate housing systems for the performance of finishing beef cattle. It is not possible to draw conclusions on overall animal welfare based on the variables examined in the current meta-analysis. It would have been desirable to include additional variables in order to evaluate the effect of floor type on animal welfare, however, it is difficult to collate data from a large number of studies due to the diverse range of response variables used and the varying methods of quantifying the results in the different housing systems. Perhaps if future housing studies are carried out, using similar approaches, it may facilitate a meta-analysis with a larger sample size in order to gain a better understanding of how cattle interact with the housing environment.

Conflict of interest

The authors have no conflicts of interest.

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Table 1: Description of the database used in the meta-analysis, the floor type comparisons each paper examined and the characteristics measured.

| References | CSF - RM | CSF - ST | ADG ¹ | FCR ² | Carcass Weight | Lying time | Dirt Scores |
|--|----------|----------|------------------|------------------|----------------|------------|-------------|
| Lowe <i>et al.</i> (2001) | x | x | x | x | x | | x |
| Hickey <i>et al.</i> (2003) | | x | x | x | x | x | x |
| French <i>et al.</i> (2004) | | x | x | x | | | |
| Gottardo <i>et al.</i> (2003) | | x | x | x | x | | |
| Moloney <i>et al.</i> (2005) | x | | x | | | | |
| Gygax <i>et al.</i> (2007) | x | x | | | | x | |
| Platz <i>et al.</i> (2007) | x | | | | | x | |
| Schulze Westerath <i>et al.</i> (2007) | x | x | | | | | x |
| Graunke <i>et al.</i> (2011) | x | | x | x | x | x | x |
| Rouha Muelleder <i>et al.</i> (2012) | x | x | | | | x | |
| Cozzi <i>et al.</i> (2013) | x | | x | x | x | x | |
| Brscic <i>et al.</i> (2015a) | | x | x | | x | | |
| Brscic <i>et al.</i> (2015b) | x | | x | | x | | |
| Earley <i>et al.</i> (2015) | x | | x | x | x | x | x |
| Elmore <i>et al.</i> (2015) | x | | | | | x | x |
| Keane <i>et al.</i> (2015) | x | | x | x | x | | x |
| Earley <i>et al.</i> (2017) | x | | x | x | x | x | x |
| Keane <i>et al.</i> (2017) | | x | x | x | x | x | x |

¹ Average daily live weight gain² Feed conversion ratio

CSF = concrete slatted floors

RM = rubber mats

ST = straw

Table 2. Differences in performance and welfare variables between CSF and RM.

| | CSF | RM | SE | P-value | n |
|-----------------------------|------------|-----------|-----------|----------------|----------|
| ADG (kg) | 1.19 | 1.26 | 0.06 | 0.112 | 8 |
| FCR¹ | 8.47 | 8.12 | 0.51 | 0.260 | 7 |
| Carcass weight (kg) | 352 | 356 | 7.8 | 0.290 | 8 |
| Lying time (hrs/day) | 13.3 | 13.2 | 0.87 | 0.655 | 8 |
| Dirt scores | 39.0 | 40.7 | 3.29 | 0.280 | 8 |

CSF = concrete slatted floors

RM = rubber mats

SE = standard error

n = number of studies used in the comparison

¹Kilograms of dry matter intake divided by kilograms of liveweight gain

Table 3. Differences in performance and welfare variables between CSF and ST.

| | CSF | ST | SE | P-value | n |
|-----------------------------|------------|-----------|-----------|----------------|----------|
| ADG (kg) | 1.16 | 1.20 | 0.109 | 0.243 | 7 |
| FCR¹ | 9.08 | 8.60 | 0.797 | 0.168 | 6 |
| Carcass weight (kg) | 347 | 350 | 8.9 | 0.587 | 7 |
| Lying time (hrs/day) | 13.4 | 13.8 | 0.97 | 0.139 | 4 |
| Dirt scores | 42.5 | 34.1 | 4.34 | 0.426 | 5 |

CSF = concrete slatted floors

ST = straw

SE = standard error

n = number of studies used in the comparison

¹Kilograms of dry matter intake divided by kilograms of liveweight gain