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Effect of floor type and space allowance on the performance and welfare of finishing beef cattle

Key external stakeholders:

Beef farmers; Teagasc KT, Bord Bia, Department of Agriculture, Food and the Marine (DAFM), veterinary surgeons.

Practical implications for stakeholders:

The outcome/technology or information/recommendation is

- Housing beef cattle on rubber mats (RM) or straw instead of concrete slatted floors (CSFs) had no effect on animal performance or animal welfare.
- Cattle housed on RM overlaid on CSFs had a greater number of hoof lesions.
- Providing finishing beef cattle with space allowances above 3.0 m^2 per animal did not improve animal performance or animal welfare.
- It is necessary to account for the animal live weight and expected animal growth rate when allocating a space allowance for finishing beef cattle.
- The use of allometric equations (e.g. equation $y=0.033w^{0.667}$) to determine space requirements is more appropriate than assigning cattle to a fixed space (m^2) per animal.

Main results:

Based on the studies conducted, the following conclusions were made:

- Covering old or new CSF with RM had no effect on live weight gain or final carcass weight.
- Beef cattle housed on RM developed a greater number of hoof lesions than those housed on CSF.
- There was no difference in the cleanliness of cattle housed on CSF or RM.
- Providing finishing beef cattle with space allowances above 3.0 m^2 per animal did not improve animal performance or animal welfare.
- Housing finishing cattle on straw instead of CSF did not improve animal performance.
- Cattle on straw spent approximately one hour longer lying per day compared to those on CSF.
- Finishing cattle housed on straw were dirtier than those on CSF after 105 days.
- Space allowances of 2.0 m^2 per head or less were inadequate for housing finishing cattle.
- The allometric equation $y = 0.033w^{0.667}$ (where y = m^2 per head, k = constant 0.033, w = bodyweight) was adequate for defining the spatial requirements for beef cattle housed on CSF.

Opportunity / Benefit:

The central objective of this research was to investigate the effects of floor type and space allowance on the performance and welfare of finishing beef cattle using objective scientific criteria. To attain this objective, three experimental studies were conducted. In addition, data from the findings of previous studies were collated and a meta-analysis performed to determine the effect of space allowance and floor type on animal performance and welfare variables. The data generated provides objective, scientifically sound guidelines to the beef industry that would safeguard the international reputation of the industry and allay possible consumer concerns.

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Collaborating Institutions: UCD

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Teagasc project team: Dr. Bernadette Earley (PI); Mr. Michael Keane (Walsh Fellow student)
Dr. Mark McGee; Dr. Edward O'Riordan
External collaborators: Dr. Alan Kelly

1. Project background:

The predominant housing systems used in Ireland are sheds with concrete slatted floors (CSF), of which there are approximately 68,000 nationwide (DAFM, 2015). Recently, there have been growing concerns regarding the welfare of beef cattle accommodated indoors, particularly in relation to floor type and space allowance (European Food Safety Authority (EFSA)). There have been calls for the use of CSF to be phased out and to be replaced by more 'welfare friendly' floor surfaces such as CSF overlaid with RM or use of straw bedding. With regard to space allowance, there have been suggestions to increase the space allowances per animal on concrete slatted floors (CSF) to 3.0 m^2 for a 500kg animal ± 0.5 m^2 per 100 kg above or below this (SCAHAW, 2001). This equates to almost doubling the current space allocation provided to finishing beef cattle.

2. Questions addressed by the project:

1. What are the effects of old and new CSFs, with and without rubber mats (RM) on the performance, dirt scores, hoof health and immune function of finishing bulls.
2. What are the effects of three space allowances (3.0, 4.5 and 6.0 m^2) on CSF, and one space allowance (6.0 m^2) on straw, on the performance, dirt scores, hoof health and immune function of finishing heifers.
3. What are the effects of space allowance and floor type on performance and welfare parameters of finishing beef cattle, determined through a meta-analysis of published data.
4. How does the performance and welfare of beef cattle housed with dynamic space allowances, defined by allometric equations, compare with that of cattle housed with fixed space allowances.

3. The experimental studies:

The overall objective of this body of work was to examine the responses of cattle to different floor types and space allowances and, therefore, determine the most suitable housing system for accommodating finishing beef cattle.

In the **first study**, continental crossbred beef bulls (n = 72; mean initial live weight = 441 (s.d. 45.1) kg) were blocked by breed and live weight and randomly assigned by block to one of four treatments; 1) Old CSF 2) New CSF, 3) Old CSF covered with RM, 4) New CSF covered with RM. Each treatment had 3 pens of 6 bulls at a space allowance of 2.9 m^2 per animal. Bulls were fed a total mixed ration (TMR) of silage and rolled barley on a 54:46 dry matter (DM) basis for 148 days. Feed was weighed into each pen daily and refusals were weighed twice weekly. Bulls were weighed every three weeks to coincide with dirt scoring. Total leukocyte, neutrophil, lymphocyte, eosinophil and monocyte percentage, red blood cell number and haemoglobin concentrations were measured on day 0 and day 148. Bull's hooves were inspected for the presence of lesions at the start of the study and again at slaughter. After slaughter, carcass weight, carcass gain, conformation and fat score, kidney and channel fat and hide weight were recorded.
The age of the CSF had no effect on animal performance or welfare (Table 1). Bulls on RM had 44% more hoof lesions ($P < 0.01$) than those on CSF. There were slat × time ($P < 0.05$) and mat × time ($P < 0.001$) interactions for dirt scores. Bulls on CSF were dirtier than those on RM on days 63, 84 and 126 ($P < 0.05$) while bulls on new CSF were dirtier than those on old CSF on days 21 and 42 ($P < 0.001$). Floor type had no effect ($P > 0.05$) on any of the haematology variables measured which suggests that the immunological status of the bulls was not affected by treatment.
While there was no evidence of lameness in bulls on RM, the increased number of hoof lesions suggests that hoof health may be compromised in bulls housed on RM.

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Table 1. Performance characteristics, carcass traits and hoof lesion scores of bulls on different floor types. Values are expressed as LS Means ± SEM

	RM		CSF			Significance		
	Yes	No	Old	New	SEM	Mat	Slat	Mat× Slat
DM Intake (kg/day)	9.4	9.4	9.5	9.3	0.15	0.55	0.29	ns
Initial weight (kg)	441	441	442	440	7.8	0.95	0.90	ns
Slaughter weight (kg)	649	623	640	632	10.6	0.08	0.61	ns
Live weight gain (kg/day)	1.41	1.24	1.35	1.31	0.04	<0.01	0.39	ns
FCR[a]	6.5	7.3	6.9	6.9	0.15	<0.01	0.89	ns
Carcass weight (kg)	364	352	359	358	6.83	0.16	0.75	ns
Est. carcass gain (kg/day)	0.79	0.71	0.75	0.75	0.03	<0.05	0.88	ns
Kill-out %	56.1	56.5	56.1	56.5	0.37	0.50	0.38	ns
Kidney and channel fat (kg)	8.17	7.31	8.06	7.41	0.3	<0.05	0.12	ns
Conformation	10.6	10.2	10.4	10.5	0.26	0.35	0.84	ns
Fat score	9.3	9.3	9.5	9.1	0.37	0.99	0.21	ns
Hide weight (kg)	51.4	47.4	50	48.8	0.99	<0.01	0.39	ns
Lesion score	16.0	11.0	15.0	13.0	0.99	<0.01	0.15	ns

RM=rubber mats; CSF=concrete slatted floor; [a] Kilograms of dry matter intake divided by kilograms of live weight gained; ns=not significant

In the **second study**, continental crossbred heifers (n=240: mean initial live; weight, 504 (S.D. 35.8) kg) were blocked by breed, weight and age and randomly assigned to one of four treatments; i), 3.0 m^2, ii), 4.5 m^2 and iii), 6.0 m^2 space allowance per animal on a concrete slatted floor (CSF) and, iv), 6.0 m^2 space allowance per animal on a straw-bedded floor, for 105 days. Heifers were offered a total mixed ration *ad libitum*. To permit direct treatment comparisons within a single shed, the straw-bedded floors were created by placing a polypropylene geotextile membrane (Synthetic Packaging, Clara, Co. Offaly, Ireland) over the CSF and the straw was placed on top of this free-draining membrane. The membrane was also placed on the surround of the pen enclosures to a height of 0.5 m to prevent movement of the straw to adjacent floor treatments. The straw-bedded pens were replenished with un-chopped barley straw at a rate of 150 kg per pen every three days and this was fully removed and replaced with fresh straw, every two weeks. Soiled bedding in the straw-bedded pens was never higher than 25 cm in depth

Dry matter intake was recorded on a pen basis and refusals were weighed back twice weekly. Heifers were weighed, dirt scored and blood sampled every three weeks. Whole blood was analysed for complete cell counts and serum samples were assayed for metabolite concentrations. Behaviour was recorded continuously using infrared cameras from day (d) 70 to d 87. Heifers' hooves were inspected for lesions at the start of the study and again after slaughter. Post-slaughter, carcass weight, conformation and fat scores, and hide weight were recorded.

Heifers housed at 4.5 m^2 had a greater average daily live weight gain (ADG) than those on both of the other CSF treatments (Table 2); however, space allowance had no effect on carcass weight. Heifers accommodated on straw had a greater hide weight and had greater dirt scores at slaughter than heifers accommodated on CSF at 6.0 m^2. The number of heifers lying at any one time was greater on straw than on CSF. Space allowance and floor type had no effect on the number of hoof lesions gained or on any of the haematological or metabolic variables measured. It was concluded that increasing space allowance above 3.0 m^2 per animal on CSF was of no benefit to animal performance but it did improve animal cleanliness. Housing heifers on straw instead of CSF improved ADG (hides were heavier with dirt) and increased lying time; however carcass weight was not affected.

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Figure 1: Effect of space allowance and floor type on the dirt scores (16-80) of beef heifers over a 105 finishing day period.

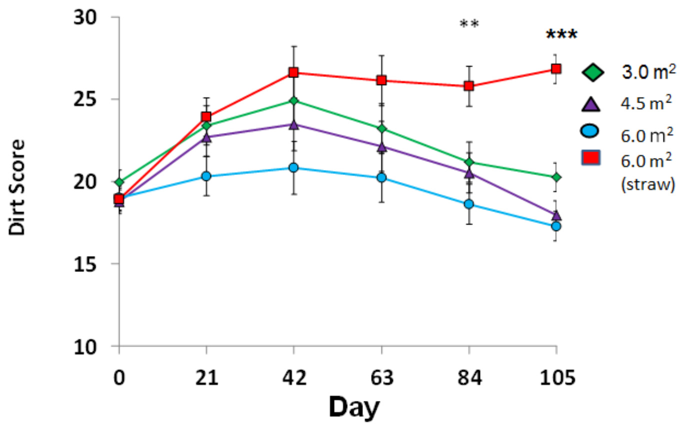

Table 2. Effect of space allowance and floor type on beef heifer intakes, performance characteristics and number of hoof lesions obtained during a 105 day finishing period.

	Space allowance (m^2/head)				**Floor type ($6m^2$/head)**			***P*-value**	
	3.0	**4.5**	**6.0**	**SEMp**	**CSF**	**Straw**	**SEMp**	**Space allowance**	**Floor type**
DM intake (kg/animal/d)	11.1	11.1	11.1	0.12	11.1	11.1	0.09	0.939	0.613
Initial weight (kg)	505	506	504	2.3	504	504	1.8	0.839	0.975
Slaughter weight (kg)	631	642	633	4.5	633[a]	648[b]	5.0	0.502	0.030
ADG (kg)[1]	1.18[a]	1.28[b]	1.19[a]	0.025	1.19[a]	1.34[b]	0.036	0.033	0.017
Feed conversion ratio[2]	9.43[a]	8.74[b]	9.45[a]	0.173	9.45[a]	8.42[b]	0.236	0.016	0.021
Carcass weight (kg)	343	344	341	2.4	341	347	2.7	0.825	0.171
Kill-out proportion (g/kg)	544	536	539	3.1	539	537	2.5	0.521	0.616
Carcass conformation score[3]	8.5	8.5	8.2	0.15	8.2	8.6	0.20	0.585	0.184
Carcass fat score[4]	10.1	10.2	10.1	0.23	10.1	10.4	0.26	0.967	0.464
Hide weight (kg)	38.5	38.5	37.6	0.46	37.6[a]	39.5[b]	0.35	0.647	0.009
Hoof lesions obtained (number)	3.0	3.3	3.0	0.41	3.0	3.1	0.28	0.904	0.726

SEM*P* = pooled standard error; CSF = concrete slatted floor; d = day;
[a,b],Least squares means within a row without a common superscript letter differ (*P* <0.05);
[1]ADG = average daily gain; [2]Kilograms of dry matter intake divided by kilograms of live weight gained;
[3]EU Beef Carcass Classification Scheme, scale 1 (poorest) to 15 (best);
[4]EU Beef Carcass Classification Scheme, scale 1 (leanest) to 15 (fattest); The values are expressed as least square means (LS Means) and SEMp.

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In the **third study**, published data from previous studies, examining the effect of space allowance and floor type on animal performance and welfare, was compiled for a meta-analysis. The keywords used to search the databases were: space allowance, floor type, beef cattle, performance, welfare, animal behaviour and animal cleanliness. A total of 22 papers were used in the analysis containing information on floor type and space allowance and their effect on ADG, feed conversion ratio (FCR), carcass weight, lying time and dirt scores (Table 3).

There was no difference in ADG, FCR or carcass weight between CSF and RM. Housing cattle at space allowances below 2.0 m^2 per head had a negative effect on ADG, FCR, lying time and carcass weight. It was concluded that housing beef cattle on RM or straw instead of CSF had no effect on performance or welfare and that further research was required to determine the optimal space requirements for finishing cattle on CSF.

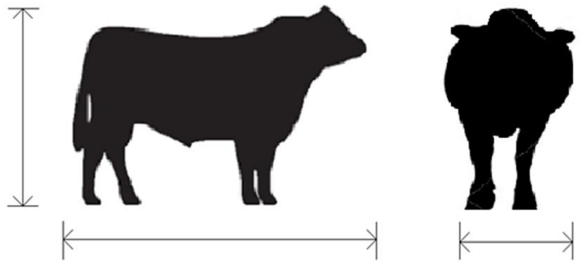
Table 3. Differences in performance and welfare variables of cattle housed on concrete slatted floors (CSF) and on rubber mats (RM).

	CSF	RM	SE	P-value	n
ADG (kg)	1.19	1.26	0.06	0.112	8
FCR[1]	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; [1]Kilograms of dry matter intake divided by kilograms of live weight gain

One way of possibly determining the optimum space for finishing cattle, irrespective of their weight, is through the use of allometric equations. Instead of allocating a fixed space allowance per animal, allometric equations use the progressing weight of an animal to estimate the space that they require during housing (Figure 2). Thus the allometric equation uses bodyweight to estimate an animal's space requirements, returning the formula $y=kw^{0.667}$, where y=surface area, k=a space allowance coefficient (constant), w=bodyweight. Furthermore, the Scientific committee for animal health and animal welfare (SCAHAW, 2001) recommended that beef cattle expected to reach 500 kg should be provided with 3.0 m^2 per animal, ± 0.5 m^2 for every 100 kg above or below this level. In allometric terms, the SCAHAW (2001) recommendation equates to a space allowance defined by the equation $y = k(0.048w)^{0.667}$. To date, no study has evaluated the use of allometric equations, using dynamic space allowances, for housing beef cattle on CSF. Thus, the objective of study four, was to compare the performance and welfare of beef cattle housed on CSF at two different dynamic space allowances, defined by Petherick and Phillips (2009) and SCAHAW (2001), to that of cattle housed at three different fixed space allowances. Our study hypothesis was that providing finishing beef cattle with dynamic space allowances, defined by allometric equations, would be more beneficial, for performance and welfare, than providing them with a fixed space allowance per animal.

Figure 2. Diagram showing the three dimensions that animals utilise to occupy space.



Animals occupy space in three dimensions (height, length, width), but because the height of the available space is not usually a constraint, only the two dimensional area measurements are usually considered. Thus, allometric equations of the form area = $kw^{2/3}$, where k = a constant and w=live weight, can be used to estimate the space an animal occupies as a consequence of its mass

In the **fourth study**, continental crossbred steers (n=120: mean initial live weight, 590 (S.D. 29.8) kg)

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were blocked by breed, weight and age and assigned to one of five space allowance treatments (three fixed and two dynamic) on CSF: i) 2.0 m^2 per animal, ii) 2.5 m^2 per animal, iii) 3.0 m^2 per animal, iv) Equation 1 (E1); $y=0.033w^{0.667}$, where y = m^2 per animal and w = body weight, and v) Equation 2 (E2); $y=0.048w^{0.667}$. For the latter two treatments, the pen size increased as the animals gained weight. The feed face length was fixed at 3.0 m for all pens for the duration of the study. Steers were offered grass silage and concentrates ad libitum. Dry matter intake was recorded weekly on a pen basis. Steers were weighed and dirt scored every 14 days. Blood samples were collected every 28 days, and analysed for complete cell counts. Behaviour was recorded using closed-circuit infrared cameras. Steers' hooves were inspected for lesions at the beginning of the study and post-slaughter.

The ADG of steers housed at 2.0 m^2 was lower than steers on all other treatments except for 2.5 m^2. The carcass weights of steers at 2.0 m^2 were lower than each of the other space allowances. Steers housed at 2.5 m^2 had lower carcass weights than those with space allowances defined by k=0.033 and k=0.048, whereas the carcass weight of steers with 3.0 m^2 was intermediate. Lying duration was reduced for steers housed at 2.0 m^2 in comparison to all other treatments. The current study found that 2.0 m^2 per animal, (k-value of 0.027), is an insufficient space allowance for finishing continental crossbred beef steers based on performance and behavioural results. Furthermore, the inconsistencies between the results of previous studies examining different space allowances for finishing cattle can be explained by the weight difference of the cattle between studies, hence, it is not the m^2 per animal which affects performance, but more so the m^2 per kg. It is necessary to account for the weight and expected growth rate of finishing cattle when deciding what space allowance they should receive, therefore, it is concluded that using k-values to estimate the space cattle require is more appropriate than providing them with a certain space (m^2) per animal. The results also demonstrated that the equation $y = 0.033w^{0.667,}$ as suggested by Petherick and Phillips (2009), is sufficient for estimating the space requirements of finishing beef cattle on CSF. Using this equation ensures that the space provided to an animal is sufficient for performance and it provides adequate space for animals to perform the greater behavioural repertoire required when housed for a prolonged period. It is necessary to account for the weight and potential growth rate of finishing cattle when deciding what space allowance they should be assigned. It is concluded that using allometric equation with a constant (k value) of 0.033 (Equation 1: $y = 0.033w^{0.667}$) to estimate the space cattle require is more appropriate than providing them with a fixed space (m^2) per animal.

PETHERICK, J. C. & PHILLIPS, C. J. C. 2009. Space allowances for confined livestock and their determination from allometric principles. Applied Animal Behaviour Science, 117, 1-12.
SCIENTIFIC COMMITTEE ON ANIMAL HEALTH AND ANIMAL WELFARE (SCAHAW). 2001. The welfare of cattle kept for beef production. In European Commission, Health & Consumer Protection Directorate-General, SANCO.C.2/AH/R22/2000.

4. Main results:

Based on the studies conducted the following conclusions were made:

- Covering old or new CSF with RM had no effect on carcass weight.
- Beef cattle housed on RM developed a greater number of hoof lesions than those housed on CSF.
- There was no difference in the cleanliness of cattle housed on CSF or RM.
- Providing finishing beef cattle with space allowances above 3.0 m^2 per animal did not improve animal performance or animal welfare.
- Housing finishing cattle on straw instead of CSF did not improve animal performance.
- Cattle on straw spent approximately one hour longer lying per day compared to those on CSF.
- Finishing cattle housed on straw were dirtier than those on CSF after 105 days.
- Space allowances of 2.0 m^2 per head or less were inadequate for housing finishing cattle.
- The equation $y = 0.033w^{0.667}$ (where y = m^2 per head, k = constant 0.033, and w = bodyweight) was adequate for defining the spatial requirements for beef cattle housed on CSF.

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Table 4. Effect of space allowance on intake, performance characteristics and number of hoof lesions of finishing beef steers over a 105 day study period. Values are expressed as least square means ± SEMp.

	Space allowance, m²/steer						
	2.0	**2.5**	**3.0**	**E1[1]**	**E2[2]**	**SEMp**	***P*-value**
Grass silage DMI (kg/steer/day)	1.2	1.2	1.2	1.2	1.1	0.02	> 0.10
Concentrate DMI (kg/steer/day)	8.8	9.2	9.6	9.4	9.8	0.21	0.07
Total DMI (kg/steer/day)	10.0	10.4	10.8	10.6	10.9	0.2	0.06
Initial weight (kg)	589	593	590	590	589	2.9	> 0.10
Slaughter weight (kg)	665[a]	688[ab]	705[bc]	701[bc]	713[c]	8.1	0.038
ADG (kg)	0.76[a]	0.88[ab]	1.05[bc]	1.09[bc]	1.14[c]	0.066	0.041
FCR[1]	13.7[a]	12.0[ab]	10.3[bc]	10.1[bc]	9.4[c]	0.69	0.016
Carcass weight (kg)	389[a]	401[b]	409[bc]	411[c]	417[c]	4.9	0.01
Kill-out proportion (g/kg)	586	581	583	588	583	3.6	> 0.10
Carcass conformation score[2]	9.2	9.4	9.8	9.8	9.8	0.28	> 0.10
Carcass fat score[3]	7.9[a]	8.7[ab]	8.9[ab]	8.9[ab]	9.3[b]	0.38	0.042
Hide weight (kg)	49.1[a]	50.2[ab]	52.1[ab]	50.5[ab]	54.7[b]	1.35	0.049
Hoof lesions obtained (number per animal)	3.1	2.5	3.5	2.9	3.6	0.35	> 0.10

SEMp = Pooled SEM; E1 = space allowance per animal (m^2) = 0.033bodyweight$^{0.667}$; E2 = space allowance per animal (m^2) = 0.048bodyweight$^{0.667}$; [1]kilograms of dry matter intake divided by kilograms of live weight gained; [2]EU Beef Carcass Classification Scheme, scale 1 (poorest) to 15 (best); [3]EU Beef Carcass Classification Scheme, scale 1 (leanest) to 15 (fattest); [a, b]Least squares means within a row without a common superscript letter differ ($P < 0.05$)

5. Opportunity/Benefit:

The central objective of this research was to investigate the effects of floor type and space allowance on the performance and welfare of finishing beef cattle using objective scientific criteria. To attain this objective, three experimental studies were conducted. In addition, data from the findings of previous studies were collated and a meta-analysis performed to determine the effect of space allowance and floor type on animal performance and welfare variables. The data generated provides objective, scientifically sound guidelines to the beef industry that would safeguard the international reputation of the industry and allay possible consumer concerns.

6. Dissemination:

Main publications:

1. Keane, M. P., McGee, M., O'Riordan, E. G., Kelly, A.K. and Earley, B. (2015) 'Effect of floor type on hoof lesions, dirt scores, immune response and production of beef bulls' *Livestock Science* 180: 220-225.
2. Keane, M.P., McGee, M., O'Riordan, E.G., Kelly, A.K. and Earley, B. (2017) 'Effect of space allowance and floor type on performance, welfare and physiological measurements of finishing beef heifers' *Animal* 21: 1-10.
3. Keane, M.P., McGee, M., O'Riordan, E.G., Kelly, A.K. and Earley, B. (2017) 'Effect of floor type and space allowance on performance and welfare of finishing beef cattle: A meta-analysis' *Livestock Science* (In Review).

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4. Keane, M.P., McGee, M., O'Riordan, E.G., Kelly, A.K. and Earley, B. (2017) 'Performance and welfare of steers housed on concrete slatted floors at fixed and dynamic (allometric based) space allowances' *Journal of Animal Science* (In Review).

Popular publications:

1. BEEF open day Grange "Profitable Technologies" Improving animal health village, 5th July 2016.
2. Farmers' Journal "Does floor space affect cattle performance" 10th December 2016
3. Cattle Association of Veterinary Ireland (CAVI) conference "Space allowance for finishing beef cattle – using allometric based equations" 13-15 Oct 2017, Cork.

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