The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

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Application of the Welfare Quality® animal welfare assessment system in Finnish pig production, part II: Associations between animal-based and environmental measures of welfare

C Munsterhjelm*, M Heinonen and A Valros

Department of Production Animal Medicine, PB 57, FIN-00014 University of Helsinki, Finland
* Contact for correspondence and requests for reprints: camilla.munsterhjelm@helsinki.fi

Abstract

This study aimed to establish associations between the environment and animal-based measures of welfare collected on 158 Finnish farms according to the Welfare Quality® systems for pigs. The data consisted of 95 welfare assessments in fattening pigs and 103 in sows, including suckling piglets. Principal Component Analysis had previously been applied to animal-based welfare measures (ABWM) and to the 20 descriptors of QBA to identify distinct types of welfare problems (WPT) and mood (MT), respectively. Generalised linear modeling was used to investigate environmental (space allowance, group size, feeding arrangement, floor type and use of enrichment or bedding) effects on WPT and MT scores. Those ABWMs not contributing to the major WPTs, but occurring on more than 40% of the farms, were considered important and used as outcome variables as well. The most important environmental determinants of pig welfare were space allowance for fattening pigs, group size in gestation and in the use of bedding for both fattening pigs and gestating sows. Bedding decreased tail biting and signs of fighting when used as a fairly thick layer for fattening pigs. In sows, the benefits of bedding, including less frustration and bursitis, required a smaller amount of material than in fattening pigs. An increasing space allowance was advantageous for fattening pigs, although signs of fighting increased in very spacious bedded pens. The positive effects of space, including a decrease of tail lesions and a more positive mood continued at least up to 1.5 m² per fattening pig. Signs of resource shortage in sows increased with a growing group size according to a steepening curve.

Keywords: *animal-based welfare measures, animal welfare, environmental welfare measures, pig, Principal Component Analysis, Welfare Quality®*

Introduction

Increasing consumer awareness of food animal welfare has augmented the need for feasible assessment tools. The main focus for welfare assessment — the animal or its environment — has been subject to much debate. The earliest instruments, such as the ANI (TGI) 35L (Bartussek 1999) emphasised the latter heavily. This input-based approach has been criticised by, eg Whay and others (2003), pointing out the superiority of animal-based or output indicators as sensitive descriptors of the actual status of an individual.

At present, features of the environment and management are reassigned a role as risk factors or welfare hazards (AHAW 2012). Modern, scientifically based, on-farm welfare assessment systems, such as the Welfare Quality® (Welfare Quality® [WQ] 2009), focus heavily on outcomes. The systems do, for example, apply a method called Qualitative Behavioural Assessment (QBA) allowing the observer to subjectively describe the 'body language' of pigs according to pre-defined descriptors or expressive qualities (Wemelsfelder *et al* 2000; Wemelsfelder & Millard 2009).

Animal-based measures are, however, not without downsides. They require time-consuming data collection, interpretation may be difficult and generalisability of the results uncertain (Johnsen *et al* 2001). Validity and sensitivity issues of the WQ systems for cattle have been communicated by Knierim and Winckler (2009).

The EU Scientific Panel on Animal Health and Welfare (AHAW) has put forward a method addressing the feasibility issues of outcome measures by grouping them into 'toolboxes' or shortlists (AHAW 2012). Appropriate toolboxes are chosen in any given situation based on factors such as identified environmental hazards, the purpose of the welfare assessment and/or financial constraints. This approach resembles the ideas of Bracke (2007), suggesting an interplay between input and output measures, where the latter are used as critical control points verifying the predictions being made by the former.

The process of building comprehensive toolboxes requires thorough knowledge about the associations between animal-based welfare measures, environmental and other

Table 1 Characteristics of piglet production. (n = number of farms).

Factor	Mean	Median	Minimum	Maximum
Sow years* (n = 103)	223.1	123	30	2,000
Culling rate % (n = 75)	38.1	34.8	0.0	114.8
Farrowing rate % (n = 17)	77.6	79.9	56.2	91.6
Litters per sow per year (n = 19)	2.2	2.2	1.8	2.6
Piglets weaned per sow per year (n = 19)	22.5	22.4	15.9	28.7
Weaning age (days; n = 99)	30.8	31	23	50
Litter size at birth (n = 18)	13.3	13.4	12.0	14.9
Litter size born alive (n = 18)	11.9	11.8	10.5	13.2
Litter size weaned (n = 16)	9.9	9.9	8.6	11.6
Piglet mortality % at birth (n = 19)	10.5	10.6	4.9	17.3
Piglet mortality % birth to weaning (n = 76)	12.2	12.1	1.5	22.7
Piglet mortality % total (n = 19)	24.4	22.8	17.0	36.1

* The number of days spent on the farm summarised for all sows, divided by 365.

hazards and the nature of the consequences for animal welfare. These relationships may be extremely complicated, to the degree of a 'multilayer web of associations' as described by AHAW, and their establishment obviously needs large amounts of data (AHAW 2012; pp 13–17).

This research aims to establish associations between the environment and animal-based welfare measures in pigs. Outcome data are collected according to the WQ protocols for sows and piglets and for fattening pigs. The WQ systems were developed by an extensive research collaboration within the 6th EU Framework Programme in 2004–2009, and they provide standardised ways of gathering information (Forkman & Keeling 2009).

The results from this study will contribute to the AHAW goal of developing 'toolboxes' for pig welfare assessment, which obviously requires a large database of systematically collected data. Moreover, if features of the environment or management show strong links to welfare, they can be communicated to stockpeople and to the industry as good practices that have a potential to facilitate the adaptation of pigs to the production environment.

Materials and methods

Sampling, farms, WQ-assessments and collection of environmental data

Only an overview is given here, as details are described in Munsterhjelm *et al* (2015; this issue). The study included 158 pig farms, introduced as a random sample (n = 106), voluntarily (n = 24) or as requested by slaughterhouse companies (n = 28). The random sample was drawn from a national database and stratified in order to emphasise a future, or large, size. Voluntary farms asked for an assessment themselves. Slaughterhouse companies used WQ results for advisory purposes when signing new contracts and when screening the welfare status on their farms.

The farms practiced pregnant gilt or sow (n = 2), piglet (n = 59), pregnant sow and piglet (n = 1), slaughter pig (n = 55) or integrated production (n = 41). These figures included two sow pool central units, caring for insemination and gestation, and four farms keeping these sows during lactation. Altogether, 95 WQ assessments were performed in fattening pigs (30–110 kg) and 103 in sows and piglets (sows in all production stages and suckling piglets). Production characteristics are summarised in Tables 1 and 2.

Data were collected according to the WQ protocol for growing pigs and for sows and piglets (referred to as 'pig categories'; Welfare Quality® 2009) by one of six trained assessors. On 40 farms with integrated production both pig categories were assessed. In order to receive information on the production environment, input measures included in the WQ-assessment (relative number and cleanliness of drinkers, space allowance) were complemented by data collected according to the categories given in Table 3, in a total of six gestation pens, five farrowing pens and 10–15 pens for fattening pigs per herd. Additionally, the farmer was asked for the quality of enrichment or bedding material, productivity figures, mortality and slaughterhouse records.

The main features of the production systems on the study farms are outlined in Munsterhjelm *et al* (2015; this issue). A typical fattening unit had part-slatted floors and liquid trough-feeding. Housing on deep litter or outdoors was not practiced, nor on fully slatted floors, except in a minority of pens on two farms. On most farms sows were kept stalled in early pregnancy and thereafter in small groups (median = 11) with a space allowance of 2.56 m^2 per sow (median) outside feeding stalls. The use of bedding or enrichment materials is detailed in Table 4. Space allowance and *k*-values for fattening pigs are plotted in Figure 1.

Table 2 Characteristics of slaughter pig production. (n = 95 if not stated otherwise).

Factor	Mean	Median	Minimum	Maximum
Slaughter pig capacity units	1,132	872	80	4,200
Weight at arrival† (kg; n = 31)	30.0	30.0	25.0	36.6
Slaughter weight† (kg; n = 57)	88.7	88.4	62.7	120.0
N of pigs per pen	11.4	10.0	2	240
Space allowance (m^2 per pig)	1.05	0.99	0.66	2.02
k-value§	0.06	0.06	0.04	0.13
Drinkers per 10 pigs	2.1	2.0	1.0	5.1
Bodyweight at assessment‡ (kg)	66	60	30	120
Mortality%† (n = 69)	2.0	1.8	0.5	5.2
Daily gain (g)† (n = 23)	923	920	857	978
Feed conversion ratio† (n = 9)	2.64	2.64	2.40	2.90
Carcase condemnations† whole (n = 55)	0.3	0.3	0.0	1.2
Carcase condemnations† partial (n = 51)	5.4	5.5	0.1	15.0
Lean meat percentage†	59.6	59.6	57.9	62.1

† For one year preceding the assessment; ‡ Estimated average for each pen; § *k*-value = $[m^2] \times$ bodyweight$^{-0.67}$.

Table 3 Additional environmental data collected on-farm.

Variable	Categorisation
Amount of bedding[1]	0 = Nothing
	1 = Only enrichment material, renewed twice daily
	2 = Bedding, thin (> 50% of the solid floor visible)
	3 = Bedding, thick (< 50% of the solid floor visible)
	4 = Deep litter
Cleanliness of bedding (sows only)	0 = No bedding in pen
	1 = < 55% of bedding clean
	2 = 55–85% of bedding clean
	3 = > 85% of bedding clean
Floor quality	0 = Totally slatted
	1 = Part-slatted
	2 = Solid
	3 = Deep litter
Housing system (sows only)[2]	0 = Gestation stalls
	1 = Unprotected simultaneous feeding (floor or trough)
	2 = Feeding stall, self-locking or open[3]
	3 = Protected individual or unprotected semi-individual feeder[4]
Feed type	0 = Liquid
	1 = Dry

[1] Each pen was assigned to a category according to the amount of material visible on the floor during the assessment, or for category 1, as communicated by the stockperson; [2] For fattening pigs feeding system was classified using categories 1 and 3; [3] Simultaneous feeding; [4] 2–3 sows may have eaten simultaneously at unprotected feeders.

Tables 4 Use of bedding and enrichment materials as percentages of farms (n = 158).

Factor	Fattening pigs	Gestating sows[1]	farrowing pens
Amount of bedding or enrichment material			
Barren pen	0%	3%	12%
Enrichment only	64%	38%	28%[2]
Thin bedding (> 50% of the solid floor visible)	28%	27%	35%
Thick bedding (< 50% of the solid floor visible)	7%	19%	21%
Deep litter	0%	13%	3%
Quality of enrichment			
Straw or hay	72%	74%	62%
> 1 non-toy material[3]	51%	28%	26%
Toy and material(s)[3]	32%	8%	4%
Toy only	0%	0%	2%
Cleanliness of bedding			
No bedding		41%	
< 55% of bedding clean		16%	
55–85% of bedding clean		21%	
> 85% of bedding clean		22%	

[1] Average for early, mid and late pregnancy; [2] Includes two farms with toys only; [3] Chewable.

Statistical analysis

Univariate tests

Statistical analyses were conducted using SPSS software (SPSS Inc, Chicago, IL, USA; version 21). Piglet data were excluded from statistical analyses due to a small number of litters sampled (10 per farm). Effects of the environment, farm type (integrated vs fattening for fattening pigs; piglet producer vs integrated for sows and piglets) and size (capacity units [CU] or sow-years [the number of days spent on the farm summarised for all sows, divided by 365] as both categorised and continuous variables), management- and assessment-related factors as given in Table 4, month of assessment (n = 10) and assessor ID (n = 6) on the prevalence of each animal-based welfare measure were determined using an appropriate test according to the distribution of the data. Normally distributed variables were analysed using Student's *t*-test or a one-way ANOVA. Non-parametric variables were analysed using a Mann-Whitney *U*-test or Kruskal-Wallis ANOVA. Correlations between animal-based and environmental variables of continuous nature (weight of the pigs, space allowance) was investigated by calculating the Spearman correlation coefficient (r_s).

Features of housing and feeding typically changed several times during one production cycle for the sows, causing a need to reduce the environmental information in order to facilitate statistical testing. Middle (roughly second gestation month) and late pregnancy (third gestation month) were thus combined to one phase. A few farms changing the environment between these stages were described by averages for the affected variables.

The following variables were used to describe the environment for sows and piglets: feed type and the amount of bedding was expressed as the average for the three stages of gestation; whereas group size and space allowance were noted separately in early and mid-late pregnancy. The relative number of drinkers was noted only in groups in mid-late pregnancy, as early pregnancy was mostly spent in stalls with individual drinkers. The farrowing pen was described by floor quality, enrichment or amount of bedding available for the sow, and size of the pen.

Principal Component Analysis (PCA)

The information included in the animal-based welfare measures, as well as in the 20 descriptors of QBA, was reduced using PCA as described in Munsterhjelm *et al* (2015; this issue). For both pig categories, three main components were identified per analysis, whose quality as scales measuring underlying constructs was generally acceptable to good. The components can thus be thought to describe distinct types of welfare problems (WPT) and mood (MT; Munsterhjelm *et al* 2015; this issue).

The WPTs seemed to describe: 1) fighting; 2) lack of bedding; and 3) (infectious) disease in growing pigs, and: 1) lack of bedding; 2) lack of resources; and 3) lack of fibre in sows (for details see Munsterhjelm *et al* 2015; this issue). The MTs described active positive, passive negative and passive positive behaviours in both cate-

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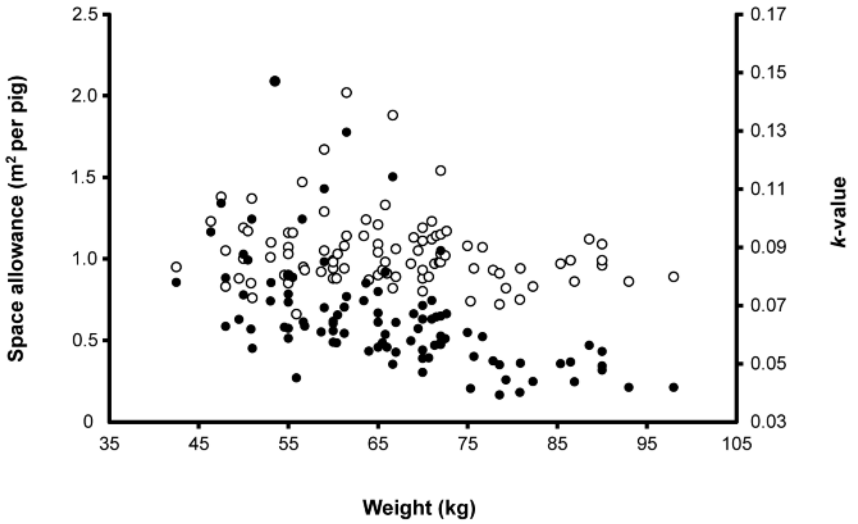
Figure 1



Space allowance plotted with empty dots on the left axis and *k*-value ($[m^2] \times bodyweight^{-0.67}$) with filled dots on the right axis in relation to bodyweight on farms raising fattening pigs (n = 95). Data are given on farm level as an average of assessed pens (10–15 per farm) on the day of assessment.

gories of pigs. Each case (farm) was assigned a score for each WPT and MT using the regression method of the factor analysis-feature in SPSS 21. Checking the scores for outliers lead to removal of two farms raising fattening pigs. One farm, utilising a full bed of wood-shavings for the first two weeks before moving the pigs to part-slatted pens, was an outlier for the WPT 'fighting'; and the other one, showing an exceptionally high percentage of negative social behaviour, for the WPT 'disease'.

Generalised linear modeling

GLMM was used to regress environmental variables on WPT and MT scores, and on those variables dropped during the PCA process occurring on more than 40% of farms and showing a (nearly) significant association ($P < 0.1$) and for continuous variables also $r_s \geq 0.30$ with any environmental feature in univariate analyses. Variables dropped from the PCA were included as they may still be relevant in terms of pig welfare (eg tail lesions in fattening pigs, for discussion see Munsterhjelm *et al* 2015; this issue). Additional variables eligible for GLMM analyses were tail lesions, 'found dead'-type mortality, coughing, sneezing, human-animal relationship, dirtiness, hernias, and thin animals in fattening pigs; as well as lameness, shoulder sores, negative social behaviour, exploration of enrichment and local infections in sows. Measures collected as two variables with different severity (score 1 and 2) were summated to one.

Normality was the probability distribution for most outcome variables in the GLMM analyses. Normality was approached by transformations including adding the smallest value of the variable and raising the result in the power given in parentheses as follows: for fattening pigs' dirtiness, 'fighting' WPT, 'disease' WPT and active positive MT (0.25), and mortality (0.5). For sows, 'lack of resources' and 'lack of fibre' WPTs (0.25), 'lack of bedding' WPT (0.50), active positive MT (1.2) and passive negative MT (0.05). Other WPTs and MTs were normally distributed. Sneezing in fattening pigs and exploration of enrichment in sows could not be normalised and were dropped from further analyses. For all other variables, Poisson was the probability distribution. Percentages were transformed to counts by rounding to the nearest integer.

In analyses on fattening pigs, floor quality was not included as a predictor due to difficulties in categorising the floor on five farms changing it during the growth period. For the four satellite units (housing the sows only during lactation), environmental variables from the central units (housing the sows during rest of the production cycle) were used. The variables, floor quality and amount of bedding in fattening pigs, as well as amount and cleanliness of bedding in sows, were correlated and thus could not be included in the same models. If both were significant the one producing the best fit of the model was chosen.

GLMM models were built by backward elimination. Assessor ID, month of assessment, farm type, farm size and, for growing pigs, weight were kept in the models if $P < 0.1$. The fit of each model was assessed based on normality of the residuals as judged by the explore-feature in SPSS, plotting of residuals versus predicted values for homoscedasticity and investigation of leverage values for possible outliers. Pair-wise contrasts within significant categorical predictors were calculated with a Bonferroni correction for multiple comparisons.

Table 5 Significant univariate effects of the environment on prevalence of animal-based signs of welfare, scored according to the Welfare Quality® assessment system for sows and piglets (n = 103 farms). Piglets are not included except for in the Qualitative Behaviour Assessment (QBA) score. Spearman correlation coefficients are given in brackets.

Measure			Bedding		Feeding system		Space allowance			
	Farm size[1]	Feed type[2]	Cleanliness	Amount	Early pregnancy[3]	Mid-late pregnancy[3]	Early pregnancy	Mid-late pregnancy	Farrowing	Group size early pregnancy
Mortality ('found dead') 1 year	*									
Bursitis, score 1 (worst leg)	*	***	***	**				(–0.35***)	(–0.30**)	
Bursitis, score 2 (worst leg)	* (0.32**)			*		***				
Shoulder sores, score 1			†							
Shoulder sores, score 2			**							
Dirtiness, score 1			**							
Dirtiness, score 2			**							
Lameness, score 2	†									
Wounds, score 2			*							
Vulva lesions, score 1						†				
Constipation			†							
Local infections, score 2						†				
Negative social behaviour					**					
Explorative behaviour										
Pen fittings		*	***	***						
Enrichment or toys			***	***	***		(0.50***)			(0.40**)
Stereotypies	*	**	***	***	†					
Fear of humans, score 2										
QBA score (farm level)		**	**	*	†					

[1] Sow-years (the number of days spent on the farm summarised for all sows, divided by 365) considered both continuous and categorised; Mann-Whitney *U*-test; [2] Dry vs liquid during pregnancy, Mann-Whitney *U*-test;
[3] Gestation stall, feeding stall, feeder, simultaneous unprotected; Kruskal-Wallis ANOVA. Score 2 refers to a more severe grade than score 1. Asterisks indicate significance: † $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Results

Univariate analysis

Univariate analysis results for sows and growing pigs are summarised in Tables 5 and 6, respectively. The animal-based measures are not defined in the table, but short definitions can be found in Munsterhjelm *et al* (2015; this issue), and complete ones in the WQ protocols (WQ 2009). Results on univariate analyses on WPTs and MTs are not shown.

Environmental effects on animal-based measures of welfare

Environmental effects on animal-based welfare measures in multivariate analyses are summarised in Table 7 for sows. Measures predicted by significant models, but without significant effects of the production environment are excluded from the table and include mortality, shoulder sores, negative social behaviour and fear of humans. Environmental features unassociated with animal-based measures were farm size and type and the environment in early pregnancy (group size, space allowance or feeding system) and in the farrowing pen (size, bedding).

The WPT explaining the largest part of total variability in the (reduced) data, that is, 'lack of bedding'; was predicted by the amount of bedding and type of feed during gestation. Ignoring the category with 'no bedding, no enrichment' (n = 3), an increasing amount of bedding had an almost linear decreasing effect on the WPT score (that is, on signs of lack of bedding). Pair-wise contrasts between the categories of bedding amount were significant ($P \leq 0.01$) except for the comparisons between thin and thick bedding, and thick bedding and deep litter. Feed type was a non-significant predictor ($P = 0.09$), but necessary for model fit. Dry feeding was the more favourable alternative.

The second most important WPT, 'shortage of resources', worsened with increasing group size in mid-late pregnancy.

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Table 6 Univariate effects of the environment on animal-based signs of welfare, scored according to the Welfare Quality® assessment system for growing pigs (n = 95 farms). Spearman correlation coefficients are given in brackets. Only measures with significant effects are shown.

Measure	Farm type[1]	Feed size[2]	Bodyweight[3]	Floor type[4]	Space allowance[5]	Bedding[6]
Mortality ('found dead') 1 year		(0.38***)				
Body condition						***
Bursitis, score 1 (worst leg)				***		***
Bursitis, score 2 (worst leg)		*				
Dirtiness, score 1		†	(0.38***)			
Dirtiness, score 2		*		*		
Lameness, score 1				**		
Wounds, score 1				**		*
Wounds, score 2						*
Tail lesions, score 1[7]	*	†	† (0.37***)		(–0.36***)	
Coughing			(0.38***)		(–0.36***)	
Sneezing			(0.33**)		(0.37***)	
Hernia, score 1	**					†
Condemnations, 1 year						
Pericarditis	*	†		†		
Pneumonia	*					
Pleurisy						*
Liver		†		†		†
Negative social behaviour		*	(0.37***)	*		†
Explorative behaviour						
Pen fittings				**		
Fear of humans, score 2				**		
QBA score (farm level)						***

[1] Integrated versus fattening, Mann-Whitney *U*-test; [2] CU considered both categorised and continuous, Kruskal-Wallis ANOVA; [3] Farm average at assessment; [4] Only part-slatted (n = 81) and solid (n = 9) included, Mann-Whitney *U*; [5] Per 100 kg; correlation; [6] Categories: no bedding but daily enrichment, thin/thick bedding; Kruskal-Wallis ANOVA; [7] Not included in the calculation of WQ scores, but assessed on-farm. Asterisks indicate significance: † $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

The same was true for the third WPT 'lack of fibre', which was affected by mid-late pregnancy feeding system as well. Feeders (non-simultaneous feeding, protected or unprotected) were favourable as compared to feeding stalls (simultaneous feeding, stalls lockable or non-gated; $P = 0.04$) and non-protected simultaneous feeding (NSF; $P = 0.02$). The feeding system was not confounded by group size, although NSF was more common in small and feeders in large groups. The GLMM result was visualised by plotting predicted scores for real ranges in the data to find that the (negative) effect of group size did not override the (positive) effect of feeding system (plot not shown). At the largest group sizes present in the data (excluding outliers: 30 for NSF, 50 for feeding stalls and 160 for feeder) the ranking of feeding systems remained, although with small differences.

The most important MT in sows and piglets, 'active positive behaviour', was decreased by gestation stalls in mid-late pregnancy as compared to both NSF ($P = 0.001$) and feeding stalls ($P = 0.01$). NSF was superior to feeding stalls ($P = 0.006$), whereas feeders did not differ from the other alternatives. An increasing group size during this stage was favourable. No bedding, but daily enrichment (average during the whole pregnancy) predicted lower scores than all categories of bedding (vs thin; $P = 0.09$, thick; $P = 0.001$, deep litter; $P = 0.000$).

Environmental effects on animal-based welfare measures in multivariate analyses are summarised for fattening pigs in Table 8. Measures producing significant GLMM models, but not predicted by the environment included lean animals, coughing, hernias and fear of humans (not included in the

Table 7 Environmental effects on welfare problem types derived from a Principal Component Analysis of animal-based measures from the Welfare Quality® assessment system for sows and piglets on 103 farms, and on mood types derived from a PCA on the descriptors of Qualitative Behaviour Assessment. Welfare problem and mood types are named (in citation marks) according to their composition (see footnotes).

Welfare indicator				Weaning to farrowing		Mid-late gestation	
	Variance explained[1]	Assessor ID	Month	Amount of bedding[2]	Feed type[3]	Feeding system[4]	Group size
Welfare problem types							
'Lack of bedding'[5]	22.2%	***	*	***	†		
'Lack of resources'[6]	22.0%	***	***			*	**
'Lack of fibres'[7]	20.0%	**	***			*	**
Mood types							
'Active positive'[8]	41.7%	***	**	***		***	*
'Passive negative'[9]	20.7%	***					
'Passive positive'[10]	12.4%	***	*				

[1] In a reduced data set; [2] Categorised as no, enrichment only, thin bedding, thick bedding, deep bed; [3] Dry versus liquid;
[4] Categorised as floor or trough without partitions, feeder, feeding stalls, gestation stalls;
[5] Exploration of pen fittings, bursitis, QBA score and stereotypies;
[6] Vulva lesions, skin and body condition, wounds;
[7] Constipation in early pregnancy, wounds, dirtiness;
[8] Playful, positively occupied, happy etc;
[9] Bored, frustrated, aimless etc;
[10] Relaxed, calm, content etc.
Asterisks indicate significance in GLMM models: † $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 8 Environmental effects on welfare problem types derived from a Principal Component Analysis of animal-based measures from the Welfare Quality® assessment system for growing pigs on 95 farms, on mood problem types derived from a PCA on the descriptors of Qualitative Behaviour Assessment, and on prevalent animal-based measures of welfare.

	Main effects							Interactions	
	Assessor ID	Month	Farm type[1]	Farm size	Bedding[2]	Weight	Space allowance	Weight × space allowance	Bedding × space allowance
Welfare problem types									
'Fighting'[3]	***	***			*		*		*
'Lack of bedding'[4]	***	***							
'Disease'[5]	**								
Mood types									
'Active positive'[6]	***								
'Passive negative'[7]	***	***							
'Passive positive'[8]	***				*	†		†	
Animal-based welfare indicators									
Dirtiness (≥ 20% of body soiled)	***	*		*					
Tail lesions (any fresh lesion)	***	***	***		***	***	***	***	
Mortality ('found dead')			†	***					

[1] Integrated vs fattening; [2] Categorised as no, thin or thick layer; [3] Bursitis, wounds, lameness;
[4] Bursitis, exploration of pen fittings, exploration of enrichment and the QBA score;
[5] Negative social behaviour, pericarditis and pneumonia condemnations;
[6] Lively, positively occupied, active etc;
[7] Indifferent, bored, aimless etc;
[8] Relaxed, calm, content, enjoying etc.
Asterisks indicate significance in GLMM models: † $P < 0.1$, * $P < 0.05$, *** $P < 0.001$.

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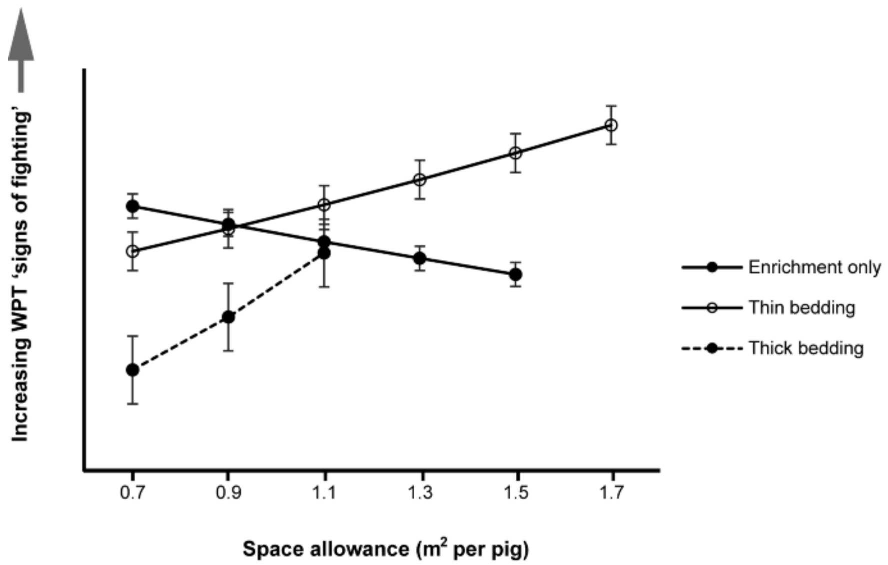
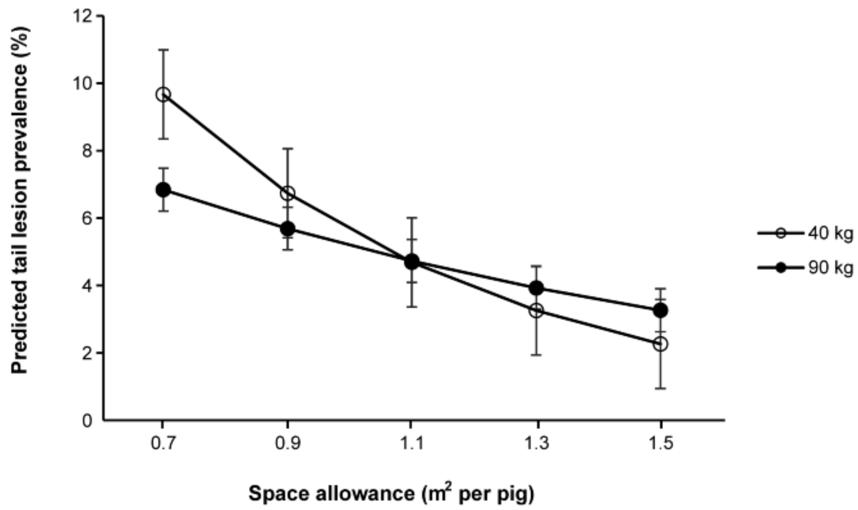
Figure 2



Predicted effect of the interaction between the amount of bedding and space allowance (farm level average of assessed pens) given as mean (± SEM) on the WPT ('welfare problem type', a principal component score) summarising skin condition, wounds and lameness in fattening pigs.

Figure 3



Mean (± SEM) predicted tail lesion prevalence in relation to farm-level average weight and space allowance. Calculations are based on the farm type (integrated) and the amount of bedding (no bedding, but daily enrichment) that predict the largest prevalence of tail lesions.

table), as well as the 'disease' WPT and the active positive and passive negative mood types.

The most important WPT, 'fighting', was worsened by increasing space allowance in bedded pens, with an opposite effect in unbedded ones. Predicted effects calculated for the values present in the data are plotted in Figure 2. The WPT 'lack of bedding' was worsened linearly by an increasing CU, although the effect was non-significant and the magnitude smaller than that of month. The passive positive mood type was strengthened by thick as compared to thin ($P = 0.04$) or no ($P = 0.03$) bedding, and (non-significantly) by increasing weight. A (non-significant) interaction between space allowance and weight indicated that increasing space allowance (m^2 per pig) strengthened the MT more rapidly in larger than in smaller animals.

Dirtiness in fattening pigs (defined as ≥ 20% of the body soiled by faeces) was most strongly affected by month, followed by CU. The smallest farm size category (CU < 350) predicted the least and the second smallest (CU 350–700) the largest amount (contrast $P = 0.02$) of dirty pigs, with no other pair-wise effects. Tail lesions (score 1 + score 2; any fresh lesion) were decreased by thick as compared to thin ($P < 0.001$) or no ($P < 0.001$) bedding and farm type fattening as opposed to integrated. An interaction between weight and space allowance showed that although both decreased the prevalence of tail lesions, small pigs were more sensitive to crowding (Figure 3). The 'found dead'–type of mortality was larger in integrated as opposed to fattening farms, and increased with increasing CU.

Discussion

This study used data from Welfare Quality® assessments of welfare in sows (n = 103) and fattening pigs (n = 95) in Finland. The aim of relating environmental factors to animal-based signs of welfare was achieved by reducing animal-based information into principal components representing welfare problem types and mood types as described in Munsterhjelm *et al* (2015; this issue), and regressing environmental measures on their scores. The main WPTs (seemingly) reflected fighting in fattening pigs and lack of bedding in both animal categories. The descriptors of QBA included distinct mood types that were close to identical in both pig categories.

The results regarding sows and piglets have to be interpreted in light of all the piglet data being omitted from the PCA analyses due to insufficient contribution to the main components. Piglet welfare does thus only affect the MTs and the WPT 'lack of bedding', as these include (farm-level) QBA information.

Farm size was associated with several welfare measures in univariate analyses. These proved to be confounded by the environment, as only a few remained significant in multivariate models, and only in fattening pigs. An increasing capacity (CU) was generally unfavourable, increasing 'found dead'-type mortality, likely due to a relative decrease in attention by stockpeople, and the WPT 'lack of bedding'. The latter effect was only nearly significant and perhaps confounded by environmental factors or management. Dirtiness in fattening pigs was affected by CU as well, but the extremes were found in the two smallest herd sizes.

Farm type affected 'found dead'-type mortality and tail-lesion prevalence, with the integrated type more unfavourable than the fattening. Continuous filling of sections, characteristic for integrated production (although not recorded in this study) comes with a number of factors that may explain these effects, including mixing of groups and compromises in environment and feeding due to a variable size of pigs. The effect may include confounding with herd size, as all the largest units were of the fattening type.

The amount of bedding was the most influential environmental feature predicting pig welfare in this study. It affected the most important WPTs in both sows ('lack of bedding') and fattening pigs ('fighting'), the prevalence of tail lesions, as well as the MTs 'passive positive' in fattening pigs and 'active positive' in sows and piglets. For all outcomes, except the 'fighting' WPT, the effect was expected, that is, an increasing amount of material predicted a change favourable in terms of pig welfare.

The importance of bedding is not surprising, as it is recognised as one of the most important resources for pigs with effects on many aspects of health and behaviour. Manipulable materials not only serve to satisfy the inherent need to explore (Beattie & O'Connell 2002), but also provides nutritional stimulus, thermal and physical comfort (Fraser *et al* 1991). The presence of bedding may also affect the assessor. The QBA procedure is known to be sensitive to contextual bias, however, Wemelsfelder *et al* (2009) point out that it does not compromise the basic reliability of an assessment.

The beneficial changes in MTs and in the sow WPT 'lack of bedding' probably arise as a summative effect of the above cited beneficial qualities of bedding material. Literature also supports the preventive effects on bursitis (included in 'lack of bedding' in sows; Mouttotou *et al* 1999; Temple *et al* 2012) and tail lesions (Fraser *et al* 1991; Day *et al* 2002; Van de Weerd *et al* 2005).

Looking at the pair-wise contrasts of the different amounts of bedding, sows seem to have responded to a smaller amount than fattening pigs. The largest difference in predicted values for 'lack of bedding' and 'active positive behaviours' was between 'no bedding' (but twice daily enrichment) and 'thin layer' in sows. In fattening pigs, however, the largest change in predicted values for tail-lesion prevalence and for the passive positive MT was thin and thick layer. The reason for a different cut-off point relative to pig size is unclear. Fattening pigs may be more sensitive to the cooling effect of a non-heated concrete floor than sows due to relatively larger skin areas, and would thus require a thicker layer of insulation for the same overall effect. In the Finnish climate, insulation of the lying area is a more important factor than coping with excess heat.

Although bedding proved to be a very influential factor, even larger effects could have been expected, especially for fattening pigs. The 'lack of bedding' WPT and the active positive MT were unaffected in fattening pigs in contrast to sows. The difference may be due to the smaller variability in the amount of material used on fattening as compared to sow farms, as deep litter was absent in the former.

The lack of completely barren pens may also have decreased the impact of bedding in the present fattening pigs. The ways of providing enrichment in non-bedded pens may, in fact, have been fairly successful due to several factors known to enhance the stimulus value. Chewable materials (Fraser *et al* 1991; Van de Weerd *et al* 2003) were used on all farms and on most of them complexity (Olsen *et al* 2000) was achieved through combinations of different materials with or without toys. Additionally, novelty (Moinard *et al* 2003) was produced by providing the enrichment twice daily.

The magnitude of the most prevalent WPT 'fighting' in fattening pigs was predicted by space allowance (SA; m^2 per pig) in an interaction with bedding. In non-bedded pens, increasing SA decreased signs of fighting, whereas in bedded pens they became more prevalent. The result may seem confusing, as the literature would imply that both SA and environmental enrichment will *decrease* aggressive behaviour and/or signs thereof (eg O'Connell & Beattie 1999; van de Weerd & Day 2009) as well as manipulation of pen-mates (Jensen & Pedersen 2010). However, previous observations suggest that the effect may be enrichment-induced increases in play or aggressive behavior, as reported by Hotzel *et al* (2009) and (for sows) by Whittaker *et al* (1999), that may be enhanced by an increase in overall activity in response to increasing space as reviewed by (Averos *et al* 2010).

Increasing SA was generally favourable in terms of fattening pig welfare. It decreased the prevalence of tail lesions and tended to strengthen the passive positive MT in

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accordance with a review by AHAW (2005), concluding that crowding increases pen-mate manipulation, aggression, skin lesions, tail-biting and stress.

SA interacted with weight to predict the passive positive MT in fattening pigs in a way showing a more rapid increase in the MT with increasing space the larger the animals grew. This effect is logical given the fact that the pens became somewhat crowded in the heaviest end of pigs in this study (farm average 90 kg) with the lowest farm level k-values ([m^2] × bodyweight$^{-0.67}$) at about 0.05, when k = 0.048, thought to be a cut-off point for negative crowding effects (AHAW 2005).

Group size did not affect growing pig welfare in this study, probably due to the very small variability. The contrast was true for sows, for which an increasing group, in mid-late pregnancy, predicted increases in the WPTs 'shortage of resources' and 'lack of fibre'. The effects may be explained by actual shortages in resources or by more complicated social relations in large groups. The risk for social stress is further augmented if pens are not managed all-in-all-out (Mendl *et al* 1992), which is more likely in very large than in small groups.

An increasing sow group size predicted a stronger active positive MT, although the magnitude of this (non-linear) effect did not become significant until the group size was large. The more positive mood in large as compared to small sow groups may be due to formation of sub-groups in the former, known to decrease aggressive behaviours (Gonyou 2001).

The feeding system for sows in mid-late pregnancy affected the WPT 'lack of fibre' and the active positive MT, with individual feeder as the most favourable system. The interpretation of this result is, unfortunately, complicated by the low number of farms in the 'feeder' category (n = 8). Moreover, excessive heterogeneity was present with both electronic feeders with restricted rations and simple, mechanically functioning devices with semi-restricted availability of food included.

Assessor ID had a profound effect on animal-based welfare measures in multivariate analyses, implying that significant subjectivity existed in the scoring process on-farm. Inter-observer reliability issues for the cattle WQ systems have been reviewed by Knierim and Winckler (2009) who described them as 'alarming'. Published data on inter-observer reliability for pig WQ systems are limited. Repeatability of lameness scoring was judged as good by Geverink *et al* (2009), and of the QBA score by Wemelsfelder *et al* (2000) and Rutherford *et al* (2012), although the latter used free-choice profiling in contrast to the fixed qualitative rating scale method used for QBA in the WQ assessment. Confounding of the assessor effect by geographical area cannot, however, be ruled out, as farms were assigned to assessors based on location.

Month was a significant predictor for most animal-based variables, with the relatively largest effect on 'dirtiness' in fattening pigs. This is not surprising, at least from a Finnish point of view, as seasonal differences in temperature and light conditions are significant in this part of the world. Although pig houses with a few exceptions are insulated, heated and mechanically ventilated, each season presents its own challenge regarding climate control.

Animal welfare implications and conclusion

This study established associations between the environment and animal-based measures of welfare collected according to the Welfare Quality® systems of pigs and grouped into distinct types of welfare problems and mood types by applying Principal Component Analysis. The associations provide information about environmental hazards for certain types of welfare problems in pigs, the most important of which in these data were slight crowding in fattening pigs, a large group size in sows and a lack of bedding in both categories of animals. The welfare problem types are shortlists of animal-based measures that can be developed into 'toolboxes' for welfare assessment on-farm to be applied upon identification of the characteristic hazard, as outlined by AHAW (2012).

References

AHAW (EFSA Panel on Animal Health and Welfare) 2005 The welfare of weaners and rearing pigs: effects of different space allowances and floor types. *The EFSA Journal 268*: 1-19

AHAW (EFSA Panel on Animal Health and Welfare) 2012 Statement on the use of animal-based measures to assess the welfare of animals. *The EFSA Journal 10(6)*: 2767

Averos X, Brossard, L, Dourmad JY, de Greef KH, Edge HL, Edwards SA and Meunier-Salaun MC 2010 A meta-analysis of the combined effect of housing and environmental enrichment characteristics on the behaviour and performance of pigs. *Applied Animal Behaviour Science 127*: 73-85. http://dx.doi.org/10.1016/j.applanim.2010.09.010

Bartussek H 1999 A review of the Animal Needs Index (ANI) for the assessment of animals' well-being in the housing systems for Austrian proprietary products and legislation. *Livestock Production Science 61*: 179-192. http://dx.doi.org/10.1016/S0301-6226(99)00067-6

Beattie VE and O'Connell NE 2002 Relationship between rooting behaviour and foraging in growing pigs. *Animal Welfare 11*: 295-303

Bracke MBM 2007 Animal-based parameters are no panacea for on-farm monitoring of animal welfare. *Animal Welfare 16*: 229-231

Day JEL, Burfoot, A, Docking, CM, Whittaker X, Spoolder HAM and Edwards SA 2002 The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. *Applied Animal Behaviour Science 76*: 189-202. http://dx.doi.org/10.1016/S0168-1591(02)00017-5

Forkman B and Keeling L 2009 *Assessment of Animal Welfare Measures for Sows, Piglets and Fattening Pigs. Welfare Quality® Reports no 10*. Cardiff University: Cardiff, UK

Fraser D, Phillips PA, Thompson BK and Tennesen T 1991. Effect of straw on the behaviour of growing pigs. *Applied Animal Behaviour Science 30*: 307-318. http://dx.doi.org/10.1016/0168-1591(91)90135-K

Geverink NA, Meuleman M, Van Nuffel A, Van Steenbergen L, Hautekiet V, Vermeulen K, Lammens V, Geers R, van Reenen CG and Tuyttens FAM 2009 Repeatability of a lameness score measured on farm. Assessment of animal welfare measures for sows, piglets and fattening pigs. In: Forkman B and Keeling L (eds) *Welfare Quality® Reports No 10: Assessment of Animal Welfare Measures for Sows, Piglets and Fattening Pigs.* Cardiff University: Cardiff, UK

Gonyou HW 2001 The social behaviour of pigs. In: Keeling LJ and Gonyou HW (eds) *Social Behaviour in Farm Animals* pp 147-176. CABI Publishing: Wallingford, Oxon, UK. http://dx.doi.org/10.1079/9780851993973.0147

Hotzel MJ, Lopes EJC, de Oliveira PAV and Guidoni AL 2009 Behaviour and performance of pigs finished on deep bedding with wood shavings or rice husks in summer. *Animal Welfare 18*: 65-71

Jensen MB and Pedersen LJ 2010 Effects of feeding level and access to rooting material on behaviour of growing pigs in situations with reduced feeding space and delayed feeding. *Applied Animal Behaviour Science 123*: 1-6. http://dx.doi.org/10.1016/j.applanim.2009.12.015

Johnsen PF, Johannesson T and Sandøe P 2001 Assessment of farm animal welfare at herd level: many goals, many methods. *Acta Agriculturae Scandinavica, Section A – Animal Science 51(30)*: 26-33

Knierim U and Winckler C 2009 On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. *Animal Welfare 18(4)*: 451-458

Mendl M, Zanella AJ and Broom DM 1992 Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour 44*: 1107-1121. http://dx.doi.org/10.1016/S0003-3472(05)80323-9

Moinard C, Mendl M, Nicol CJ and Green LE 2003 A case control study of on-farm risk factors for tail biting in pigs. *Applied Animal Behaviour Science 81*: 333-355. http://dx.doi.org/10.1016/S0168-1591(02)00276-9

Mouttotou N, Hatchell FM and Green LE 1999 Prevalence and risk factors associated with adventitious bursitis in live growing and finishing pigs in south-west England. *Preventive Veterinary Medicine 39(1)*: 39-52. http://dx.doi.org/10.1016/S0167-5877(98)00141-X

Munsterhjelm C, Heinonen M and Valros A 2015 Application of the of the Welfare Quality® animal welfare assessment system in Finnish pig production, part I: Identification of subscales using psychometric theory. *Animal Welfare 24*: 151-160. http://dx.doi.org/10.7120/0 9627286.24.2.151

O'Connell NE and Beattie VE 1999 Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. *Animal Welfare 8*: 269-279

Olsen AW, Vestergaard EM and Dybkjaer L 2000 Roughage as additional rooting substrates for pigs. *Animal Science 70*: 451-456

Rutherford KM, Donald RD, Lawrence AB and Wemelsfelder F 2012 Qualitative Behavioural Assessment of emotionality in pigs. *Applied Animal Behaviour Science 139(3-4)*: 218-224. http://dx.doi.org/10.1016/j.applanim.2012.04.004

Taylor NR, Main DCJ, Mendl M and Edwards SA 2010 Tail biting: a new perspective. *The Veterinary Journal 186*: 137-147. http://dx.doi.org/10.1016/j.tvjl.2009.08.028

Temple D, Courboulay V, Velarde A, Dalmau A and Manteca X 2012 The welfare of growing pigs in five different production systems in France and Spain: assessment of health. *Animal Welfare 21*: 257-271. http://dx.doi.org/10.7120/09627286.21.2.257

Van de Weerd HA and Day JEL 2009 A review of environmental enrichment for pigs housed in intensive housing systems. *Applied Animal Behaviour Science 116*: 1-20. http://dx.doi.org/10.1016/j.applanim.2008.08.001

Van de Weerd HA, Docking CM, Day JEL, Avery PJ and Edwards SA 2003 A systematic approach towards developing environmental enrichment for pigs. *Applied Animal Behaviour Science 84*: 101-118. http://dx.doi.org/10.1016/S0168-1591(03)00150-3

Van de Weerd HA, Docking CM, Day JEL and Edwards SA 2005 The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. *Animal Science 80*: 289-298. http://dx.doi.org/10.1079/ASC40450289

Welfare Quality® 2009 *Assessment Protocol for Pigs*. Welfare Quality® Consortium: Lelystad, The Netherlands

Wemelsfelder F, Hunter EA, Mendl MT and Lawrence AB 2000 The spontaneous qualitative assessment of behavioural expressions in pigs: first explorations of a novel methodology for integrative animal welfare measurement. *Applied Animal Behaviour Science 67*: 193-215. http://dx.doi.org/10.1016/S0168-1591(99)00093-3

Wemelsfelder F and Millard F 2009 Qualitative indicators for the on-farm monitoring of pig welfare. In: Forkman B and Keeling L (eds) *Welfare Quality® Reports No 10. Assessment of Animal Welfare Measures for Sows, Piglets and Fattening Pigs*. Cardiff University: Cardiff, UK

Wemelsfelder F, Nevison I and Lawrence AB 2009 The effect of perceived environmental background on qualitative assessments of pig behaviour. *Animal Behaviour 78*: 477-484. http://dx.doi.org/10.1016/j.anbehav.2009.06.005

Whay HR, Main DCJ, Green LE and Webster AJF 2003 Animal-Based measures for the assessment of welfare state of dairy cattle, pigs and laying hens: consensus of expert opinion. *Animal Welfare 12*: 205-217

Whittaker X, Edwards SA, Spoolder HAM, Lawrence AB and Corning S 1999 Effects of straw bedding and high fibre diets on the behaviour of floor fed group-housed sows. *Applied Animal Behaviour Science 63*: 25-39. http://dx.doi.org/10.1016/S0168-1591(98)00243-3