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Temperature profile in double-decker transporters and some consequences for pig welfare during transport

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Introduction

Adequate ventilation during transport has been emphasized repeatedly in legislation and various welfare schemes to safeguard animal welfare during transport. One practical method of measuring the effectiveness of ventilation is to measure temperature inside the vehicle and compare this with outside temperatures, smaller differences being expected to be indicative of better ventilation. There are, however, no published data on how temperature varies within a vehicle for different outside temperatures. The aim of this work, which was part of a project to evaluate optimal tier heights, ventilation openings and stocking densities in double-decker pig transporters, was to investigate the temperature variation within the vehicle during experimental transports at different times of the year. In addition, heart rate (HR) was measured in randomly chosen pigs to evaluate the effect of transport on this parameter. Finally, some information from the routine journeys with the experimental vehicle was obtained.

Material and methods

A detailed description of the experimental vehicle is given in Christensen and Barton Gade (1996). Only a few aspects will be mentioned here. Each tier was divided into four compartments of 15 pigs at a stocking density of 286 kg/m^2, the Danish norm at that time. Ventilation openings ran along both sides of both tiers and could be varied continuously from 0 to 350 mm (lower tier) and 0 to 500 mm (upper tier). The vehicle was also equipped with mechanical ventilation, although this was not used during the experimental journeys to simulate current practice. For routine journeys the mechanical ventilation systems were used, both when the vehicle was stationary (loading) and continuously during transport when environmental temperatures reached about 20°C. The vehicle also had a misting system that was used intermittently during transport when environmental temperatures reached about 25°C. Three experiments were carried out with a total of 16 individual journeys (Table 1).

In the August/September experiment, four different stocking densities: 200, 238, 263 and 286 kg/m^2 and standardized ventilation openings/tier heights were used; otherwise stocking density was 286 kg/m^2. The pigs were three or four breed crosses between Landrace, Large White, Duroc and Hampshire and had a live weight of 100 to 105 kg. Temperature was measured at five points in each compartment above the pigs (Table 2) and relative humidity (RH) at the centre of each compartment. Temperature and RH were also measured outside the vehicle, above the driver's cabin.

Measurements were recorded when both tiers were laden during transport to the abattoir. Rolling averages were calculated for temperatures at the various points in the vehicle and values obtained at constant intervals directly compared using correlation and regression analysis. In all journeys two pigs from each compartment were randomly chosen at loading and equipped with HR monitors (Schutte *et al.*, 1996). HR curves were first scanned visually and those with obvious defects rejected (9% of the total). When curves had intermittent loss of contact that allowed an evaluation of approximate

Table 1 *Temperature range and ventilation openings/ tier heights used in the three experiments*

Time of year	Temperature (°C) Mean	Temperature (°C) Range	Ventilation openings/tier heights (mm) Low tier		Upper tier	
January/February	3	(–4 to 6)	150/900	150/1100	350/ 900	350/1100
June	18	(14 to 23)	350/900	150/1100	350/1300	150/1300
August/September	19	(15 to 27)	350/900	350/1100	350/ 900	350/1300

Table 2 *Temperature measuring points in the experimental vehicle as viewed from above and nomenclature used*†

	Front compartment									Rear compartment	
	111	112	113	121	122	123	131	132	133	141	142	143
Lower tier		114			124			134			144	
		115			125			135			145	
	211	212	213	221	222	223	231	232	233	241	242	243
Upper tier		214			224			234			244	
		215			225			235			245	

† The first digit = tier, the second = compartment within tier and the third = measuring point within compartment

level this was inserted, after which rolling averages were calculated according to A. Schutte (1995, personal communication). In routine journeys, where ventilation openings were normally 350 mm on both tiers and tier heights 900 and 1300 mm for lower and upper tiers respectively, a number of details were registered over a 27-month period: numbers and placement of animals on the vehicle, number of pigs dead during transport and where the death occurred. In all 216 227 slaughter pigs were transported during this period to four different abattoirs. Journey times, i.e. time from loading the first pig to off-loading the first pig at the abattoir varied from 45 min to 3 h 5 min with an average time of 1 h 57 min.

Results

Temperatures inside the vehicle were not related to the tier heights/ventilation openings or stocking densities used but mainly to environmental conditions. A preliminary analysis on pooled data showed that measuring point 111 in the front lower compartment was affected by heat from the motor/ transmission and that there were problems with cables to measuring point 5 in several compartments. The statistical analysis was therefore restricted to points 2, 3 and 4 in the eight compartments, 24 measuring points in all. There are many combinations between these measuring points and as the final aim of this analysis was to pinpoint possible

Table 3 *Relationship between temperatures measured at the centre in the front lower compartment and other points in the vehicle and calculated values at selected temperatures*

Regression equation		R^2	RMSE	Selected temperatures (°C) 5	10	15	20	25
°C 112 = −0·7303 + 1·0018	°C 114	0·96	1·3	4·3	9·3	14·3	19·3	24·3
°C 113 = 2·2306 + 0·8904	°C 114	0·83	2·6	6·7	11·1	15·6	20·0	24·5
°C 122 = −1·1995 + 0·9848	°C 114	0·95	1·4	3·7	8·6	13·6	18·5	23·4
°C 123 = −0·7136 + 0·9781	°C 114	0·97	1·2	4·2	9·1	14·0	18·8	23·7
°C 124 = −1·7868 + 1·0268	°C 114	0·96	1·3	3·3	8·5	13·6	18·8	23·9
°C 132 = −3·8423 + 1·0594	°C 114	0·95	1·5	1·5	6·8	12·0	17·3	22·6
°C 133 = −2·8407 + 1·0057	°C 114	0·94	1·6	2·2	7·2	12·2	17·3	22·3
°C 134 = −3·6544 + 1·0740	°C 114	0·96	1·5	1·7	7·1	12·5	17·8	23·2
°C 142 = −5·2695 + 1·0734	°C 114	0·94	1·8	0·1	5·5	10·8	16·2	21·6
°C 143 = −5·2707 + 1·0857	°C 114	0·94	1·8	0·2	5·6	11·0	16·4	21·9
°C 144 = −3·6836 + 1·0550	°C 114	0·94	1·7	1·6	6·9	12·1	17·4	22·7
°C 212 = −2·7656 + 1·0157	°C 114	0·93	1·7	2·3	7·4	12·5	17·5	22·6
°C 213 = −2·8648 + 1·0198	°C 114	0·93	1·8	2·2	7·3	12·4	17·5	22·6
°C 214 = −2·5201 + 1·0275	°C 114	0·93	1·8	2·6	7·8	12·9	18·0	23·2
°C 222 = −4·2272 + 1·0656	°C 114	0·93	1·8	1·1	6·4	11·8	17·1	22·4
°C 223 = −5·0671 + 1·0800	°C 114	0·93	1·9	0·3	5·7	11·1	16·5	21·9
°C 224 = −3·5878 + 1·0551	°C 114	0·93	1·9	1·7	7·0	12·2	17·5	22·8
°C 232 = −5·1460 + 1·0607	°C 114	0·93	1·9	0·2	5·5	10·8	16·1	21·4
°C 233 = −5·1114 + 1·0603	°C 114	0·92	2·0	0·2	5·5	10·8	16·1	21·4
°C 234 = −4·8307 + 1·0892	°C 114	0·91	2·2	0·6	6·1	11·5	17·0	22·4
°C 242 = −4·9187 + 1·0680	°C 114	0·91	2·1	0·4	5·8	11·1	16·4	21·8
°C 243 = −5·4500 + 1·0816	°C 114	0·89	2·4	0·0	5·4	10·8	16·2	21·6
°C 244 = −5·6160 + 1·1124	°C 114	0·90	2·4	−0·1	5·5	11·1	16·6	22·2

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positions that could be used to indicate temperature levels in the whole vehicle in practice, it was decided to choose the compartment with the highest average temperature (the front lower compartment) as the basis for the comparison. The results (Table 3) showed that R^2 values between measuring point 114 and other measuring points were only exceptionally below 0·9 and that a single measurement in the front lower compartment could predict levels elsewhere in the vehicle ±2 to 5°C, depending on the actual measuring point itself (95% confidence level). Average temperature levels were highest on the front lower compartment and lowest in the rear upper compartments.

The relationships between temperatures within the vehicle and outside temperatures were slightly poorer than within the vehicle itself (R^2 values 0·83 to 0·95 and RMSE values 1·7 to 2·4, i.e. ± 3 to 5°C). Calculated values from the regression equations (Table 4) show that temperature differences were greatest in colder weather. With an outside temperature of 5°C, temperatures within the vehicle varied from 11 to 12°C in the front lower compartment to 7 to 8°C in the rear upper compartments. The differences were much smaller at higher environmental temperatures. RH was high (0·85 to 0·95) during transport for all experiments and irrespective of measuring point. This was partly due to the humidity produced by the pigs themselves and partly to the fact that the vehicle had not dried out after cleaning at the factory.

HR levels were, not unexpectedly, high just after placement of the belt, varying between 140 and 220 beats per min (b.p.m.) depending on animal. HR levels fell thereafter rapidly, as pigs became accustomed to the belt and recovered from the stress of loading. By 5 to 45 min after loading, again depending on animal, levels were of the order of 80 to 130 b.p.m. This time dependence meant that average HR was lower in pigs transported on the upper tier (average transport time 2 h 44 min) relative to those transported on the lower tier (average transport time 1 h 4 min), i.e. 123 to 126 *v.* 134 to 140 b.p.m. None of the ventilation openings/ tier heights used had any effect on average HR, despite large difference in environmental temperatures. Stocking density had no effect on average HR either, varying from 114 to 121 b.p.m. for pigs on the upper tier to 140 to 145 b.p.m. for pigs on the lower tier.

Twenty-six pigs died on the vehicle during the routine transports (0·012%). All of these were transported in the front lower compartment and eight came from the same producer.

Discussion

The results of this work show that there is a systematic variation in temperature within a fully laden vehicle during transport and that a single measurement in the front lower compartment can be used to give an indication of temperatures throughout the vehicle. RH was high during transport but critical combinations of temperature and RH, as described in the US livestock weather safety index (Grandin, 1992) were rarely encountered in the experimental journeys and then only for short periods. However, such high RH values mean that mechanical ventilation or other methods of cooling pigs (e.g. intermittent misting) would be advantageous at temperatures above about 25°C.

Mortality was low during routine journeys, although it is not possible to say whether it was lower than the national average (0·018% at that time). Not included in the mortality figures were two pigs which died during the experimental journeys, one during the January/February experiment (ventilation opening 150 mm, tier height 1100 mm) and one during the June experiment (ventilation opening 350 mm, tier height 900 mm). Both pigs originated from the same producer, both carried belts to measure HR and both died in the front lower compartment. Pigs from this producer had more cases of rapid post-mortem glycolysis and PSE-meat than pigs from other producers (P. Barton Gade and L. Christensen, 1996, unpublished material) i.e. typical signs of pigs carrying the halothane gene. The higher mortality in pigs transported in the front lower compartment was therefore probably caused by a combination of genotype and placement on the vehicle. Poorer

Table 4 *Average temperatures within the vehicle for different outside temperatures*

	Lower tier				Upper tier			
Temperature (°C)	Front			Back	Front			Back
5	11·9	10·4	8·7	7·8	9·9	9·0	8·0	7·3
15	19·5	18·4	17·2	17·2	17·7	17·1	16·3	16·3
25	27·1	26·3	26·3	25·6	25·5	25·5	24·6	25·2

ventilation seems to have been implicated, as the front lower compartment had the highest temperature. Nielsen (1981) also showed that an optimized ventilation system halved transport mortality in pigs.

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