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DMRI Consult

Optimization of transport conditions in relation to transport mortality

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Resumé

Introduction

Swedish Meats has requested optimization of a pig transport vehicle with the aim to bring down the frequency of pigs dying during transport.

One vehicle was chosen for the purpose and reconditioned based on specifications given by the Danish Meat Research Institute. Through registrations and tests the optimized vehicle, now referred to as the test vehicle, has been compared to the traditional type of vehicle normally used, now referred as the control vehicle.

One of the most essential changes comprised mounting of a mechanical ventilation and sprinkling system, which is started by temperature sensors and controlled by a PLC unit.

At the temperature of 20°C the ventilation system starts and at 25°C the sprinkling system starts water spraying in intervals. Both systems are run automatically.

Throughout 2004 the mortality rate was registered on the test vehicle as well as on the control vehicle. In addition, temperature measurements were registered in the compartment of both vehicles.

Registrations were carried out from March until February the following year, both moths included.

On the test vehicle was carried out a 4 days test in July during which pigs were transported without use of mechanical ventilation or sprinkling system. During the test, temperature was measured together with humidity, CO_2, pH and G-force.

The temperatures measured in the two areas through which the test vehicle and the control vehicle drove did not seem to differ much as to average temperature differences on an annual basis. In the area through which the test vehicle drove the average temperature was 8.8°C compared to 8.6°C in the area where the control vehicle drove.

Registrations of lower temperatures on the test vehicle have been evaluated. During the winter period, 72 transports were carried out at a temperature of 5°C or below and for duration of 15 minutes. In 27 out of the 72 transports, the temperature was below 0°C.

Jordbruksverket's regulations (SJVFS 2000:133) state that a slaughter pig with a live weight of 100 kg requires a floor space of 0.36 m^2 during transport and the max. load per sq. meter is 305 kg pig/m^2. The requirement is thus 0.41 m^2 for a pig with a live weight of 115 kg. The current registrations made during transport and during the 4 days test ranged between 0.364 and 0.388 m^2 per 100 kg pig.

Conclusion

It is evident that the test vehicle has a lower mortality rate than the control vehicle. The mortality rate registered on the test vehicle was at 0.11 ‰ against 0.7 ‰ in the control vehicle. The test vehicle transported 2 "pellegrise" and if we make correction for this, the mortality rate will be 0.04‰. If correction is made for a sow having been transported on the control vehicle together with pigs, the mortality rate of the control vehicle will be 0.65‰.

The control vehicle, which is like the traditional pig transport vehicle is not sufficiently ventilated, the natural vent holes are too small and do furthermore not provide an even distribution of the fresh air supplied the vehicle.

Loading of pigs has proved to take rather long. Of the total registered transport time the vehicle was at a stand still the half the time used for loading of pigs. A follow-up should be made on this point with the aim to minimize loading time and optimize conditions at the producer/farmer.

The ventilation system on the test vehicle ensured a considerably better climate during loading – particularly in relation to humidity and CO_2-concentration, particularly on the upper tier. During transport, the ventilating system is of less importance. It is therefore to be assumed that the long loading times are more crucial for vehicles without mechanical ventilation. It is likely that this is to a large extent the cause of the distinctly higher mortality rate for transports carried out on the control vehicle.

There was no cause for comments from the veterinary inspection on transports at a temperature of 5^{o}C or lower in relation to animal welfare not having been considered. These transports must therefore be considered satisfactory from a veterinary point of view.

Optimization of vehicles

Based on the specification requirements according to which the test vehicle had been built (Christensen, L., 1999) proposals have been made for building of vehicles in the future. The proposals are found in this report under the section “Recommendations”. The proposals have to be verified/accepted by Swedish Meats.

Background

Approx. 3 million slaughter pigs are transported in Sweden each year. The pigs are exposed to various actions during the transport, such as re-arranging of groups, loading onto and offloading from trucks, new environments plus - particularly during the summer period – a hot climate inside the compartment.

Over the past 25 years, Swedish Meats has made statistics comprising number of pigs that have died during transport and during lairage at the abattoirs. In 1981, the total mortality rate was high, yet below 2 ‰. After 1981, efforts intensified in relation to breeding, and in the years that followed the mortality rate decreased. The number of pigs that have died during transport has over the past 10 years been approx. 0.35 ‰. There has, however, been a tendency lately towards an increase of the mortality rate for pigs during transport. During the warm summer months, there is an increase in the mortality rate compared to the winter months.

In recent years where the mortality rate for pigs has increased during transport, the number of abattoirs has decreased which has resulted in transports being longer. During the same period there have been no essential changes to the transport equipment utilized nor have the genetic combination of the pigs transported changed much. Indications are thus that the transport equipment is no longer optimal in relation to the type of transports actually carried out.

A pre-analysis of transport vehicles in Kristianstad and Skara (Christensen, L., 2003) showed that the vehicles in general had too small and unevenly distributed vent openings. Some vehicles were equipped with mechanical ventilation with a reduced natural ventilation area.

Purpose and Aim

The aim of the project is to reduce the mortality among pigs during transport, identify casual relations and present proposals for optimization of the transport equipment for future vehicles.

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Materials and methods

Test vehicle

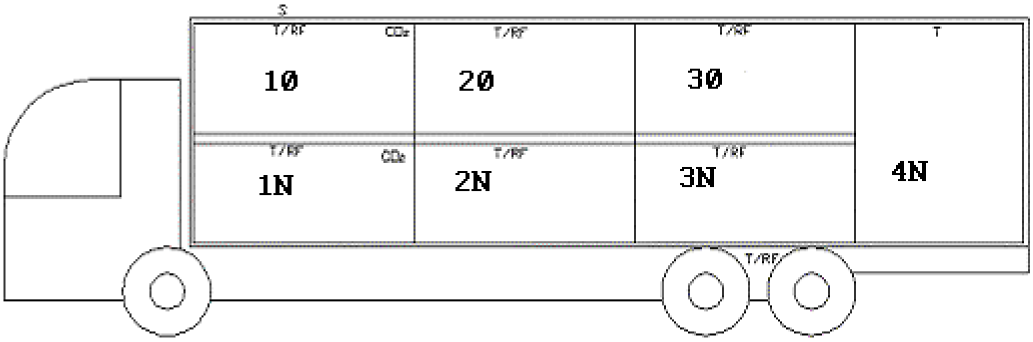
A transport vehicle (front carriage) was built in 2003 by Svabo Kaross in Kristianstad. The chassis was of the type Volvo FM12 with a small driver's cab and full air suspension. Walls and roof were the traditional 2 layers of aluminium plates with an insulation material between and cut-outs from natural ventilation. In the same cut-outs have been mounted mechanical fans. A system for sprinkling of pigs has been installed and the systems for mechanical ventilation and sprinkling are driven automatically dependant on the temperature in the compartment.

The flooring is of non-skid rubber.

Figure 1 below shows a picture of the test vehicle used for investigation of "mortality rate during 1 year's transport" and for the "4-days test"..

The design of the test vehicle and the placing of the measuring equipment have been described in detail in a separate report (Kraft, J., 2005), the most essential conditions in relation to ventilation have, however, been described in the following. The sprinkling system has not been dealt with in the report mentioned above.

Figure 2 below shows the principle design of the vehicle, the compartments and the placing of the measuring equipment.



1Ø and 1N designates compartment 1 on the upper (Ø) and on the lower (N) deck respectively. T/RF = temperature and humidity, T = temperature, CO_2 = carbon oxide, S = Pyranometer (which measures the power of the sun/solar radiation). Loggers for measuring of outdoor temperature are placed on either side of the vehicle, between the wheels.

Compartment

The lower deck has 4 compartments and the upper deck 3 compartments.

Each compartment can hold 17.2 pigs of 100 kg at 0.36 m^2/pig. Dividers between the compartments are of aluminium and have grills to facilitate passage of air between the individual compartments.

Deck heights

Lower deck has a floor-to-ceiling height during transport of 1.2 m, and the upper deck a height of 1.15 m.

Compartment 4 on the lower deck, which is the compartment furthest away from the driver's cabin has a floor-to-ceiling height equal to the two compartments together – compartment 4 being one compartment, and no upper and lower compartment.

Ventilation

Fans for natural ventilation are evenly distributed along both sides of the truck body. The truck body is furthermore equipped with mechanical ventilation. Based on calculations as to required ventilation in relation to number of pigs of 110 kg that the truck body can hold, each compartment has had a fan installed. There are thus 4 fans installed on the lower deck and 3 on the upper deck. The fans have been installed within the same area as the openings for natural ventilation and right in the middle of the individual compartment, please refer Figure 3.

The ventilation is automatically controlled and will start when the temperature goes beyond 20°C. One sensor controls the start-up, and as far as the lower deck is concerned, it is placed in the front room right behind the driver's cabin. On the upper deck the ventilation is placed in the room in the middle. Both fans are installed in the middle of the rooms.

The fans are of the type Sindby & Co. 29.30101807 and provide a volume of air of 2900 m^3/hour.

Figure 3 – Shows placing of openings for natural ventilation and the mechanical fans (1 per compartment).

Floorage and placing of ventilation openings

Floorage per compartment is shown in table 1 below.

Table 1

m^2	**Compartm.1**	**Compartm. 2**	**Compartm. 3**	**Compartm. 4**
Upper deck	6.2 m^2	6.2 m^2	6.2 m^2	
Lower deck	6.2 m^2	6.2 m^2	6.2 m^2	4.84 m^2

The aim has been to meet the requirements of the EU regulation concerning a ventilation area of 20% in relation to the total space of the individual room. The regulation does not stipulate whether the ventilation area is net or gross area.

For constructional reasons and because the truck body was already in the process of being built when it was chosen for the test it has not been possible to have a 20% ventilation area in all compartments.

Table 2

Compartment No.	1	2	3	4
		Upper deck		
Meter above floor	0.8-1.15	0.8-1.15	0.8-1.15	
Area (m^2) and % of floor	1.134 18.3	1.134 18.3	1.134 18.3	
		Lower deck		
Meter above floor	0.7-1.05	0.7-1.05	0.7-1.05	0.7-1.05 and 2.4-2.65
Area (m^2) and % of floor space	1.428 23.0	1.428 23.0	1.428 23.0	0.952 19.7

The figures mentioned are percentage of total space available.

Difference between the net ventilation and gross ventilation areas is some 30-40%. This difference is a result of the grilles used as partition between the compartments and which serve to protect the pigs from being caught and squeezed.

Since mobile decks often pass the grilles on the lower deck, please refer Figure 4, the mesh openings must be smaller than mesh openings allowed in the grille on the upper deck.

Figure 4 – Interior showing the ventilation openings and placing of the mechanical ventilation.

Control equipment, used for approx. 1 year

Above all compartments in the middle and placed like the temperature sensors have been installed a temperature logger, TinyTag Plus (Gemini Data Loggers), which constantly registers the temperature with intervals of 15 minutes. The temperature loggers have a measuring certainty of 0.6°C.

Control equipment, 4 days test

In connection with the 4 days test during which the transport as well as the slaughter process was surveyed a measuring equipment for control of relative humidity (RF) and CO2 was installed plus a set of temperature loggers (Kraft, J., 2005) which performs a registration of temperatures with intervals of 30 seconds.

G-measurings, 4 days test

For the 4 days test was installed equipment for measuring of vibrations in the truck body.

Acceleration and vibrations were measured on the upper and lower tier by 2 G-loggers from the company of Larsen and Brusgaard (Nøddegaard, F. & Brusgaard, N. 2004; Nøddegaard, F., 2004). The loggers were mounted on the floor in compartment 3 - counted from the driver's cab - of the upper/lower tier (immediately above the rear axle. The loggers were set for a lograte of 100 per second. This setting will limit the analysis to only comprise vibrations with frequencies up to 50 Hz, which is considered to be within the relevant range. Frequencies below 0.5 Hz have not been included in this report. It should be noted that with human beings travel sickness is particularly caused by low frequent vertical vibrations – particularly in the range 0.06 – 0.5 Hz.

Data was analysed in the computer programme "G-force viewer" from Larsen and Brusgaard. Vibration frequencies were calculated by FFt (Fast Fourier Transform) in the "G-force viewer" The FFT is a simplified type of the original Fourier transformation developed by Cooley and Tukey (1965).

The fore carriage was loaded with 13,114 kg and drove without trailer during the measuring.

The road surfaces were slightly corrugated unpaved roads, even unpaved roads, minor local asphalt roads and main road E4.

pH-measuring, 4 days test

For the 4 days test pH_1 was measured (30 minutes after slaughter) on the pigs involved in the test, please refer "Test Summary" page 21..

A measuring equipment of the type Knick 913 with an Electrolyt glass electrode was used for measuring of pH. Measurements were performed in the loin of the pig.

Pigs were offloaded from the test vehicle and lairaged at the abattoir in the same groups as on the transport vehicle. The pigs were slaughtered as soon as possible, i.e. they were slaughtered 0.5 to 1 hour after offloading.

Control vehicle

The floor space of the truck body is 23.5 m2 for the lower as well as the upper tier. The area of the ventilation openings on the lower tier is 3.18 m2 and on the upper tier 4.14 m2 corresponding to 13.5% and 17.6% of the floor space respectively. On the lower tier had furthermore been installed a mechanical ventilator to serve the compartments immediately behind the driver's cab. On the roof were installed 4 ventilators that among other things served the lower tier via the bearing post construction of the walls whose cross sectional area had not been measured but is estimated to be some 50 by 180 mm and thus only capable of transporting rather limited volumes of air.

The ventilation area can be adjusted via plates that will completely close each opening (stepwise adjustment is thus not possible).

Directive by the EU on 20% ventilation openings has been compensated for by mounting mechanical ventilators. This possibility has, however, not been mentioned in the EU Directive.

Adjustment of the ventilation openings on the upper tier shall be made from inside the compartment and can thus not be expected to be used during transport when there are animals inside the compartments.

Figures 5 and 6 show the control vehicle.

Figure 5 – vehicle seen from the right. Please note the ventilator in the compartment in front.

Figure 6 – Vehicle seen from the left and from above showing the openings in the roof.

Test Summary

Tests carried out

Over periods of approx. 1 year a number of tests were carried out which have been described briefly in the following summary.

1. Registration of mortality of slaughter pigs during transport from March 2004 until February 2005. Registration of the temperatures were made on both upper as well as the lower tier.
2. On 6 and 8 July as well as on 15 and 16 July 2004 pig transports were made on the test vehicle. Time used for loading and offloading, lairaging, stunning and slaughter were registered. During transport was measured temperature, humidity, CO_2 content in the compartments, G-measurements (measuring of vibrations) and on the slaughter line was measured pH_1.

   Four transports were carried out, two without and two with the mechanical ventilation running. The test comprised transport of 110 + 110 pigs with no use of mechanical ventilation, and 112 + 111 pigs with the mechanical ventilation running.

The transport vehicle in Kristianstad as well as in Skara used trailers for transport of pigs occasionally. Transports with trailers have not been registered and used for comparison of the mortality rate.

In the following are gone through the results of the above two tests individually under the headlines of “Mortality registered during 1 year of transport” and “Mortality registered during the 4 days test” respectively.

Results and discussion
1. Mortality during 1 year of transport

Registrations were made during the daily transports of the test and control vehicles in Kristianstad and Skara respectively.

The number of pigs in the individual compartments and the number of pigs that have died during transport were registered in a table, and a registration was made for each transport.

For the transport vehicle in Kristianstad were registered the temperatures in all compartments, on the vehicle in Skara registrations were made in 3 compartments only. Furthermore the outdoor temperatures were registered.

For transports during which pigs have died we know the name of the pig producer, the number of pigs per compartment and the weather conditions during transport. When possible it is also registered where in the compartment the pig died.

Outdoor temperatures

Skara, which is situation inland, may have both colder winters and hotter summers than they have in the Kristianstad area. It has proven that during the registration period there have only been few and minor temperature differences and they are deemed not to have any influence on the transport mortality.
The temperatures measured are the average temperatures between 05:00 and 18:00 hours all days when pigs have been transported. The temperatures have been very consistent, which will appear from Figure 7 below.

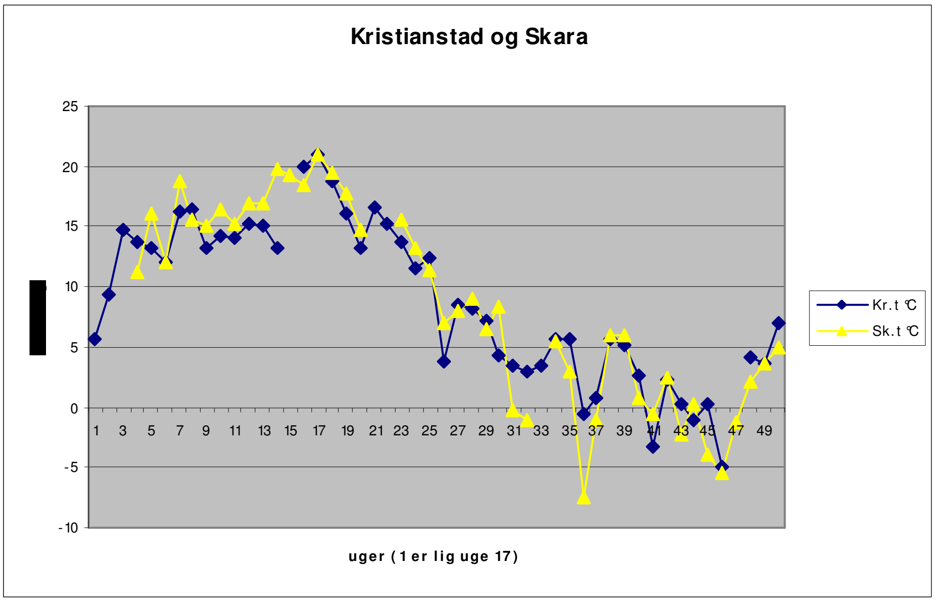


Figure 7 – Comparison of temperatures measured in Skara and Kristianstad respectively during 1 year of transport.

During the hot periods during which the transport mortality is expected to be high the temperatures in both the Skara and Kristianstad vehicles were largely the same. In cold periods where pigs died during transport the temperatures were the same (weeks 33 through 39) why we cannot say that temperature difference has an immediate effect on number of pigs dying during transport.

Mortality rate registered during 1 year of transport

A comparison has been made between the two hauliers in relation to the total number of pigs transported on the fore-carriage and the total number of pigs that have died during the transports, please refer Table 3.

Table 3

	Kristianstad	Skara	Comments
No. of transports	28,396	22,930	
No. of dead pigs	3*	16**	* incl. 2 “Pellegrise” ** incl. 1 sow
Dead ‰	0.11	0.7	
Dead ‰ (figs. Corrected for * and **)	0.04	0.65	

It can be argued whether “Pellegrise” should be transported together with ordinary slaughter pigs. The EU directive gives that pigs that vary considerably in size must not be transported together. The “varying considerably in size” has not been defined. In Denmark we use an old definition that says that “the smallest animal must not be more than 40% smaller than the largest animal”.

Sows must not be transported together with slaughter pigs unless the animals are used to each other. In such case there should be a written statement to that effect from the pig producer.

If we take a look at the mortality rate over 1 year, the mortality rate registered on the vehicle in Kristianstad is some 6 times as low as the mortality rate registered on the vehicle in Skara.

Pig producers

Apart from the difference in relation to construction and equipment of the vehicles there may be conditions relating to the producers that may have an impact. In Table 4 below is listed the pig producers that have delivered more than one pig, “Pellegris” or sow that have subsequently died during transport.

Table 4

	Kristianstad	Skara	Comments
Producer No.	[1] 74356 x 2	[2] 160 x 2 [3] 1329 [4] 478	[1] “Pellegris” [2] Week 30 or on the same day [3] Week 33 + 35 [4] Sow

Delivery of pigs from a producer who has had more than 1 pig dying during transport and whose pigs are named “Pellegris” deviate in size from other pigs in the same compartment.

As can be seen in Table 4, two “Pellegrise” and 1 sow were transported together with pigs of a normal size, 120 kg. The “Pellegrise” were registered to have a weight of approx. 60 kg. The weight of the sow was not registered.

Statistically the total number of pigs does not correspond with the number of pigs dying during transport, (if requirements for m^2 have to be fulfilled). However, there is a tendency towards some pig producers differing from others, which can be seen in the registrations of pigs.

Conditions at the place from which the animals are collected as well as conditions in connection with loading of the vehicle have not been investigated.

Mortality rate for summer and winter periods

It is well-known that frequently the mortality rate is higher for transports during summer than in the winter period. A comparison has been made of registrations made during the summer and the winter periods respectively on the Kristianstad and the Skara transport vehicles, just as a comparison has been made between the two vehicles.

Figure 8 illustrates the mortality rate registered for the test vehicle and the control vehicle respectively over the period of registration

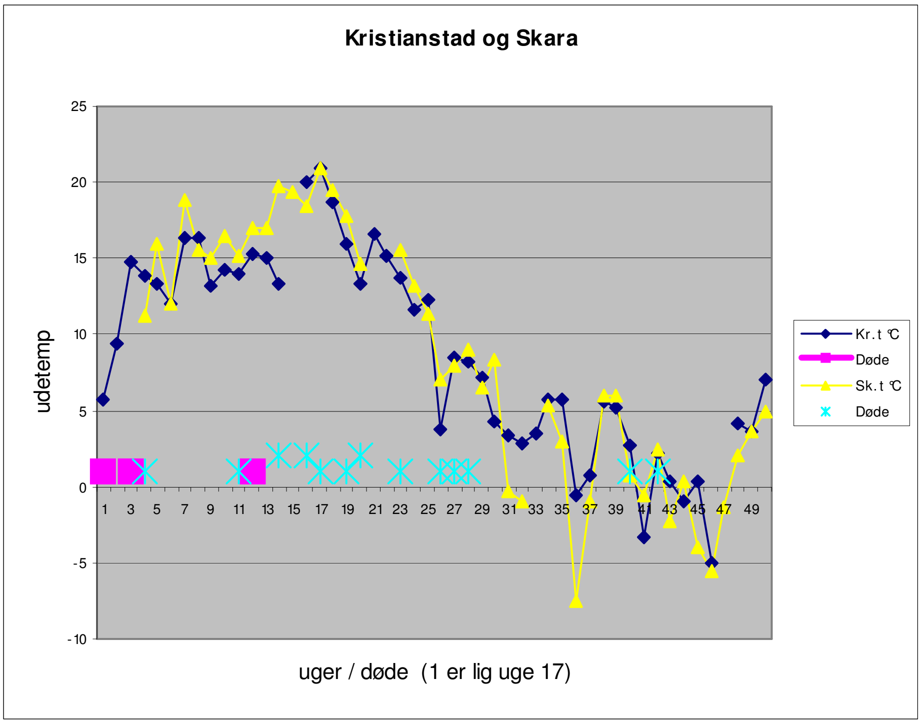


Figure 8: Temperatures registered during the period and distribution of mortality among the pigs.

Registrations of weeks for the summer period (April to September) have been set off on the x-axis from 1 to 24 representing week 17 through 40. The months of June through August are from 7 to 19 representing weeks 23 to 35/36.

As also illustrated, more pigs on the test vehicle as well as on the control vehicle die at high temperatures than at low temperatures. It is more evident on the control vehicle than on the test vehicle. The test vehicle being able to compensate for temperature rises via its mechanical ventilation system. The 3 “elevated” stars on the figure each represent 2 dead pigs. During the period where the outdoor temperature has been 15^{o}C or more 9 out of 16 pigs died.

Mortality rate at different temperature intervals

Figure 9 illustrates at which temperate intervals pigs have died during transport on the test vehicle, and Figure 10 shows corresponding figures for transports on the control vehicle.

Temperature intervals are per 5^{o}C, and reference is made to the outdoor temperatures.

Temperature in the truck body states the average of all compartments.

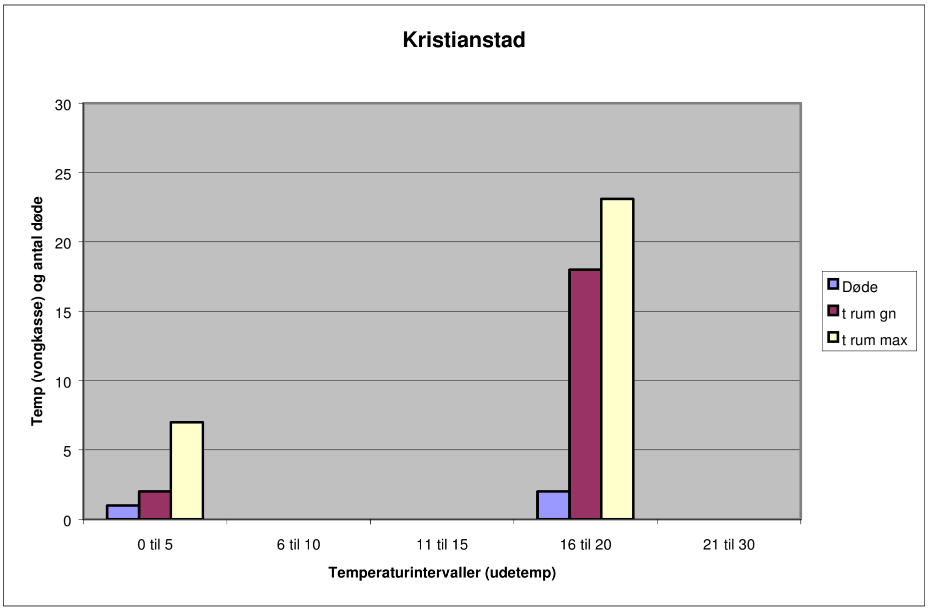


Figure 9: Temperature intervals within which pigs have died while transported on the test vehicle.

As illustrated, one pig (Pellegris) has died at a low temperature and 2 at medium temperature (1 pig and 1 Pellegris).

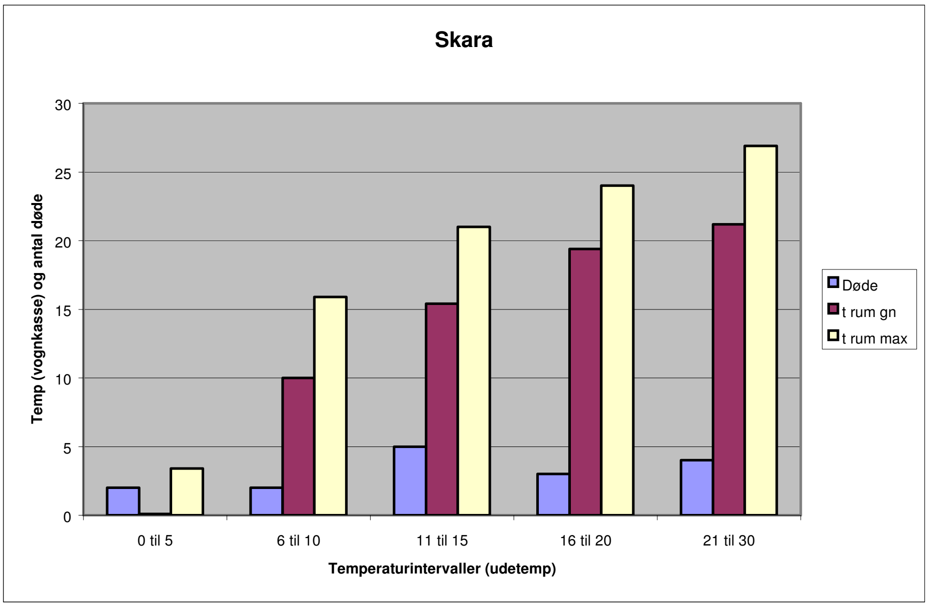


Figure 10: Temperature intervals within which pigs have died while transported on the control vehicle.

As illustrated, the number of pigs that have died are highest at the temperature interval 11-15^{o}C and then at 21-30^{o}C.

Pigs have also died at relatively low outdoor temperatures. As will appear from Figure 9 the average temperature on the test vehicle was 2^{o}C and in the control vehicle 0.1^{o}C.

Whether the pigs on the registrated transports at relatively low temperatures have died because of the low temperatures is not known. A pig supplies heat, constantly some 250 W and can only recompensate by absorption of feed. Since the time of feed absorption is not known, we cannot know whether the quantity of energy in pigs have been sufficient to maintain their body temperature or they have died of other causes

Transports during cold weather

In this report we have concentrated on the period October 2004 to March 2005 (inclusive) and solely on transports where the temperature in the truck body in one or more compartments has been 5°C or below for at least 20 minutes.

During said period there were 72 transports with temperature intervals as shown in Table 5. For transports of more than 8 hours the EU regulation demands temperatures to be between 5 and 30°C ±5°C. There are at present no demands with respect to temperatures for transports up to 8 hours.

According to report from the European Food Safety Authority (2004) the thermo neutral zone is between 14 and 32°C, and at present there is an EU bill proposing this interval for long transports, i.e. transports of more than 8 hours. The same proposal furthermore contains a requirement that deviations from this temperature interval can only be accepted for a period of max. 15 minutes. Neither of the proposals complies with the actual conditions in cold countries where pigs have to cope with these conditions.

Temp.°C	5 to 0	<0 to -5	<-5 to -10	<-10
No. of transports	45	24	2	1

Table 5: No. of transports carried out with a temperature below 5°C in the truck body.

As can be seen from the above table 27 transports are carried out at relatively low temperatures. Three of the 27 transports are even at very low temperatures. Do consider though that the temperatures are measured in the area above the pigs and will thus be higher that had it been measured between the pigs.

The length of the transports during the cold period has been registered, and distributed on time intervals, temperature groups and in relation to the total number of transports we get the result as illustration in Table 6.

Temp. °C	5 to 0	<0 to -5	<-5 to -10	<-10
≤2 hours	4 (8)	0 (0)	0 (0)	0 (0)
2 – 4 hours	29 (64)	20 (83)	2 (100)	0 (0)
>4- 6 hours	12 (38)	4 (17)	0 (0)	1 (100)

Table 6: Transports in number and percentage (%) distributed on total time of duration of the individual transports.

Transports at a temperature below 0°C have all lasted between 2 and 6 hours. The coldest transport was at a temperature of <-10°C and lasted between 4 and 6 hours.

If we consider which compartments on the fore carriage that primarily have the lowest temperatures, we find that it is compartments 2L, 3L and 4L. In 36% of the transports compartment 4L was the coldest. In cases where 2L or 3L were the coldest compartments, the temperature difference between the two compartments and 4L was max. 0.2°C. Room 4L can thus be regarded the coldest room in general.

Cold transports and the veterinary inspection

At transports during the cold periods there have been no specific comments or complaints from the veterinary inspection in relation to animals having been transported during the above mentioned temperatures. It can therefore be concluded that animal welfare has in no way been compromised from a veterinary point of view. There have been no incidents of pigs dying during transport at temperatures below 0°C.

Danish investigations of transports in cold weather

Danish investigations (Christensen, L., and Barton Gade, P., 1997) proved that the heart rate will increase at lower temperatures in order to compensate for heat loss. The investigations were made in compartments with temperatures as low as 2-3°C and during transports of max. 1 hour. Such transport time had no effect as to number of pigs dying during transport.

Another Danish investigation (Christensen, L., and Barton Gade, P., 1995) comprised measurement of temperatures above pigs as well as between pigs, and with outdoor temperatures of 12^oC and 6-7^oC respectively; the temperatures between pigs were registered 1-4^oC and 2-6^oC higher than the temperatures measured above pigs. The measuring points of the Danish investigation were identical to the measuring points used in the Swedish investigation. The actual temperatures between pigs as stated in Table 5 is thus assumed to be at least 2-6^oC higher, which, however, does not change the fact that there may still have been transports where the temperature between the pigs could have been close to -10^oC.

Loading times

There has been no systematic split of transport times into stop/loading and actual transport. A review of the transports of the 4 day test has, however, shown that time for loading of pigs comprised up to 50% of the total transport time.

Load factor at 0.42 m^2/pig

Eight transports have been carried out with the test vehicle and with a load factor of 0.42 m^2/pig. Two transports had an outdoor temperature of 2^oC, 5 had a temperature of 15-19^oC, and 1 transport had an outdoor temperature of 24^oC. 1360 pigs were transported. When comparing the mortality rate of the transports, there was only a small difference between the normal transports and the transports with a low load factor.

Transports with a load factor of 0.42 m^2/pig had no dead pigs in relation to actual m^2 of 0.364 to 0.388 m^2/100 kg. With a higher load factor, 3 Pellegrise died during transport. If correction had been made for the “Pellegrise”, the difference would have been 1 dead pig, which could have been a coincidence.

Investigation of varying load factors

Previous investigation of load factors at 0.35, 0.39, 0.42 and 0.50 m^2/100 kg live animal respectively (Barton Gade, P., and Christensen, L., 1996) showed that for transports of up to 2 hours there were some incidents of rind damage on pigs at 0.39 and 0.42 m^2/100 kg compared to load factors of 0.35 and 0.50 m^2/100 kg. No differences with respect to meat quality were observed between the individual load factors. The damages inflicted on animals with larger load factors may be explained by the fact that animals cannot support one another during transport.

2. “4 days” test

Sweden’s Agricultural University

Per request from Swedish Meats Sweden’s Agricultural University, the “Institutionen för jordbrukets biosystem och teknologi” participated in this part of the project. Participants were Professor Krister Sällvik and student Jannica Kraft. In connection with her master work, Jannica Kraft made a detailed description of her investigation (Kraft, J., 2005) why only the most important results and supplementary results that have not been included in Ms Kraft’s project will be explained in this section on the 4 days test.

Attachment 1 contains an extract from Ms Kraft’s report in Swedish.

DMRI’s comments on Ms Kraft’s results and conclusions have been included subsequently in cases where DMRI does not agree with Jannica Kraft’s interpretation of the results, or in cases where substantial scientific documentation exists and to which Ms Kraft has not referred.

Natural ventilation

Has been dealt with in Attachment 1. DMRI has no further comments.

Mechanical ventilation

Described in Attachment 1. DMRI has no further comments.

Temperature when loading and at stand still of the vehicle

Has been described in Attachment 1. It is stated that the CO_2 level during loading is higher on the upper tier than on the lower tier. This difference is reduced during transport. From Figure 14 is seen that the difference not only decreases but is actually neutralized in the course of the first 15 minutes or so of the transport.

Temperature during transport

Has been dealt with in Attachment 1. DMRI has no further comments.

Temperature in compartments compared to outdoor temperatures

The difference between the outdoor temperature and the temperature in the compartment is largest at low temperatures. Table 7 gives the difference between the total transports (stops and actual transport) during the 1-year period and at different outdoor temperatures.

Table 7

Outdoor temp.	Fore carriage, lower deck, ave. temp. °C	Fore carriage, upper deck, ave. temp. °C	Outdoor temp. Ave. temp. °C
≤9	8.9	7.7	3.5
10 to 16	16.1	16	13.7
17 to 19	18.6	18.6	16.8
≥20	22.9	22.5	20.5

With stops, the difference is larger between the outdoor temperature and the temperature in the truck body. Increases between 1 and 7.8°C are experienced, highest in the compartments that are loaded first. The variation between outdoor temperatures and the temperature in the truck body is so big that the outdoor temperature cannot be used as indicator of the temperature in the truck body.

Temperature upper/ lower tier and middle tier

There is a comparatively little difference between the temperatures on the upper and lower tiers. The difference is the largest at low temperatures. Table 8 gives the average temperature of the upper and lower tiers for all transports (stops and actual transport) during the 1-year transport and with different outdoor temperatures.

Table 8

Outdoor temp. (°C)	Fore carriage, lower deck, Ave. temp. °C	Fore carriage upper deck, Ave. temp. °C	Δ Temp. °C
Up to 9	8.9	7.7	1.2
10 to 15	16.1	16	0.1
16 to 19	18.6	18.6	0
20 to 21	22.9	22.5	0.4

The difference between the lower and upper decks varies from 0 to 1.2oC. This is not a big difference. There is, however, some difference in temperatures between the individual compartments on the lower deck, where the temperature in the two front compartments (1L and 2L) during stops is between 3.1 and 5.2°C higher than that of the other compartments on the lower deck.

Humidity

Recommendations by an EU working group on climatic conditions during transport of animals have been adopted into present legislation. The law thus describes that for transports of live animals for more than 8 hours the temperature in the truck body must be between 5 and 30°C ±5°C. The same temperature level/requirements go for transports of live animals for up to 8 hours. For the transports in connection with the “4 days investigation”, temperatures in the truck body were between 15 and 25°C that is within the temperatures recommended for long transports. The temperatures can thus be considered being within an acceptable level.

Carbon dioxide

The carbon dioxide concentration rose quickly when loading pigs on the transport vehicle, with natural as well as mechanical ventilation. With mechanical ventilation, the level of the carbon dioxide concentration was stable at the level of 2000 ppm. With natural ventilation the concentration of carbon dioxide kept rising to a level of 8000 ppm, which is the upper limit of the measuring equipment.

In her report J. Kraft demonstrates that the CO_2 level should not go beyond 3000 ppm. There is, however, no scientific example to support the quotation that animal welfare is compromised at such CO_2 level. 3000 ppm is a level chosen based on the efficiency of the ventilation, the level might have been higher without compromising animal welfare. This argument has, however, not been investigated.

Airflow J. Kraft describes in her report that there are major temperature differences between the individual compartments on the vehicle when is has been loaded with pigs. There is an actual temperature difference of 3.1 to 5.2°C (please refer section “Temperatures upper/lower deck and between compartments”)

Times for loading Has been described in Attachment 1, please also refer sections “Conclusion” and “Recommendations”.

Advantages of mechanical ventilation Has been described in Attachment 1, DMRI has no further comments.

Measurement of vibrations Vibrations during transport influence the comfort of the pigs during the transport. The influence of vibrations were investigated in the AIR project (AIR-3-CT92-0262), comprising a double deck pig transport vehicle with full air suspension. The vehicle investigated in the AIR project had its upper tier mounted on hydraulic cylinders (Randall et al.,1995). The transport vehicle used for this investigation had also full air suspension, it differed though from the vehicle used in the AIR project in that its upper tier was suspended in wires. It was thus checked whether the two different types of suspension had any impact on the comfort of pigs during transport, and whether there were other differences between the two transport vehicles in general. Randall et al. (1995) only checked vibration conditions of the lower deck and not the upper deck.

Vibration (up-down) Perremans et al. (1998) recommended to avoid vertical vibration (up-down) more than 0.43 g. In the present investigation such effect was only found for a limited time and never during transports on even and asphalt coated road.

Effect of tier In certain situations, the upper tier served as a filter that softened the high frequency oscillation. This happened during different transport conditions and to a variable degree in all axes (X, Y, Z).

In other situations the effect was the opposite; that is the high frequency oscillations increased on the upper tier but only in the X-direction (forward-return) as will appear from Table 9.

FFT-analysis of Vibration frequencies	Predominant vibration frequency, Hz					
	X direction		Y direction		Z direction	
Situation	Upper	Lower	Upper	Lower	Upper	Lower
Asphalt, E4, 88 km/h, Hz	26; 45; 7 Hz	37; 32; 26; 8 Hz	15; 7 Hz	15; 32 Hz	27; 7; 1,2 Hz	26; 23; 31; 15 Hz
g-interval**	+/-0.06	+/-0.11	+/-0.05	+/-0.11	+/-0.08	+/-0.18
Even unpaved road, 50 km/h, Hz	27-32 Hz	Variable	13-16 Hz	12-18; 30-37 Hz	1,2 Hz	Variable
g-interval**	+/-0,25	+/-0,10	+/-0,07	+/-0,15	+/-0,12	+/-0,25
Lettere korrugeret grusvej, 7-11 km/t, Hz	Variable*	Variable	Variable	Variable	2.1 Hz	1.8; 26; 17 Hz
g-interval**	+/-0.03g	+/-0.03	+/-0.04g	+/-0.03g	+/-0.15g	+/-0.16g
Between gear change during acceleration within the area 25 to 50 km/h	Increases from 30 to 37 Hz between two gear changes	Variable	Variable	variable	Drops from 37 to 30 Hz between two gear changes	Drops from 48 to 24 Hz between two gear changes
Stand-still, ventilator on, engine turned off, Hz	Variable	3 Hz	Variable	2; 12 Hz	Variable	3; 10 Hz
Stand-still, ventilators open, engine turned on, Hz	28-32 Hz	30 Hz	Variable	30 Hz	2-33 Hz	30 Hz

Table 9

Where more than one value has been stated, the values have been ranked in declining order in relation to amplitude in the FFT analysis
* Variable means that the FFT-analysis showed no stable frequency
** With no short extremes
X Forward-return direction: Y: sideways direction; Z: up-down direction

Vibrations during transport

During transport the most frequent frequencies were 26-27, 30-37, 7-8, 13-17, 1.2 Hz (mentioned in order of frequency). The international literature contains very few investigations of the physical effect vibrations have on pigs. In an investigation in relation to sucking pigs Perremans et al. (2001) conclude that on the vertical level (up-down) high frequencies (18 Hz) seems less stressful than lower frequencies (2-8 Hz). For calculation of the significance of discomfort and wellbeing in humans, the ISO system ascribes max importance of frequencies in the area around 0.6-9 Hz for all three levels (ISO 2631-1 (1997)) The frequencies within these ranges were only experienced to a limited extent during the present test transport.

Of the frequencies registered, 26-27 Hz gave most frequently the largest amplitudes in the FFT-analysis.

As mentioned by Granlund & Lindström (2004) the suspension of a vehicle is not very good at softening low-frequency vertical vibrations – particularly at high speed. This is due to such vibrations being caused by rather long ranging uneven road surfaces. The uneven surfaces often cover larger areas than the distance between the wheelbase of the vehicle, and the vehicle is therefore forced to follow the up and down curves with a very small effect on the suspension. It can be calculated that the vibration of 1.2 Hz measured on the upper tier of a pig transport vehicle driving on main road E4 at a speed of 88 km/h most likely was caused by the road swinging up and down with a wavelength of some 20 meter. Since the distance between the axles are less than 20 meter the vehicle can do nothing much than to follow the surface of the road. Improvements can only happen by changing the speed and thus the frequency and amplitude of the g-force. Further measurements are required to evaluate whether the principle of suspension of the upper tier has an impact on transference of the low frequent vibrations onto the pigs.

It was noted that when driving at a speed of 88 km/h on main road E4, the incidence of low frequent vertical vibrations (1.2 Hz) on the upper tier was larger. This indicates that the construction of the vehicle with the flexible, suspended upper tier also plays a part. This is an interesting factor since vibrations are registered in the low frequency area, which involves the largest danger of carsickness. There was, however, not found any vomit from pigs.

Balance

Turning and short stops resulting in G-force sideways and forward-return respectively made the pigs sway and toddle when the force got beyond 0.2 g. The pigs leaned against one another and against the sides/gates of the compartments. Because of the fairly good load factor (floor space some 0.38 m^2/100 kg) no pigs fell over because they had always somebody or something to lean against.

Often the pigs swayed and toddled more with simultaneous reflections on the meter both sideways and forward-return - for example when the vehicle was turning and still braking – and in particular when the braking was slackened while turning a corner. It was difficult to see any difference between upper and lower tiers since the way pigs sway depends on in which direction they are facing in relation to the direction of the G-force. The situation on the two tiers was therefore largely never identical on the two tiers. The difference between the two tiers was with respect to the pigs keeping their balance not critical.

Deceleration from 71 to 49 km/h using 3.5 seconds

Deceleration resulted in a continued X-deflection (forward-return) of approx. 0.19 g on the upper tier and approx. -0.21 g on the lower tier. The different signs are because the G-logs had been mounted 180^o opposite one another.

The reason why the small difference could be explained by the upper tier being suspended and it will thus reduce the effect on the floor of the tier in connection with braking and will to a certain extend mitigate the effect.

As basis for references should be mentioned that Nøddegaard and Brusgaard (2004) registered that an extreme and very hard braking resulting in release of the ABS-brake system and a G-force of 0.6 g in the forward-return direction on a Danish single tier vehicle.

"Mixed transport" involving acceleration, deceleration and turnings

The results of the g-measurements in connection with "mixed transport" involving acceleration, deceleration and turnings up to 180° are illustrated in Figures 14U and 14L.

Figures 11U and 11L show filtered data with median filter, factor 25. The effect on the X-axis (forward-return, blue curve), y-axis (sideways, red curve) and Z-axis (up-down, green curve) and the resulting g-force (vector total, brown curve) are shown on the left scale (-0.20 – 1.10g). Height in meter above sea level (lilac curve, 0.0 – 1.1 g) and speed in km/h (yellow curve, 0.0 – 70.0 km/h) on the right scale.

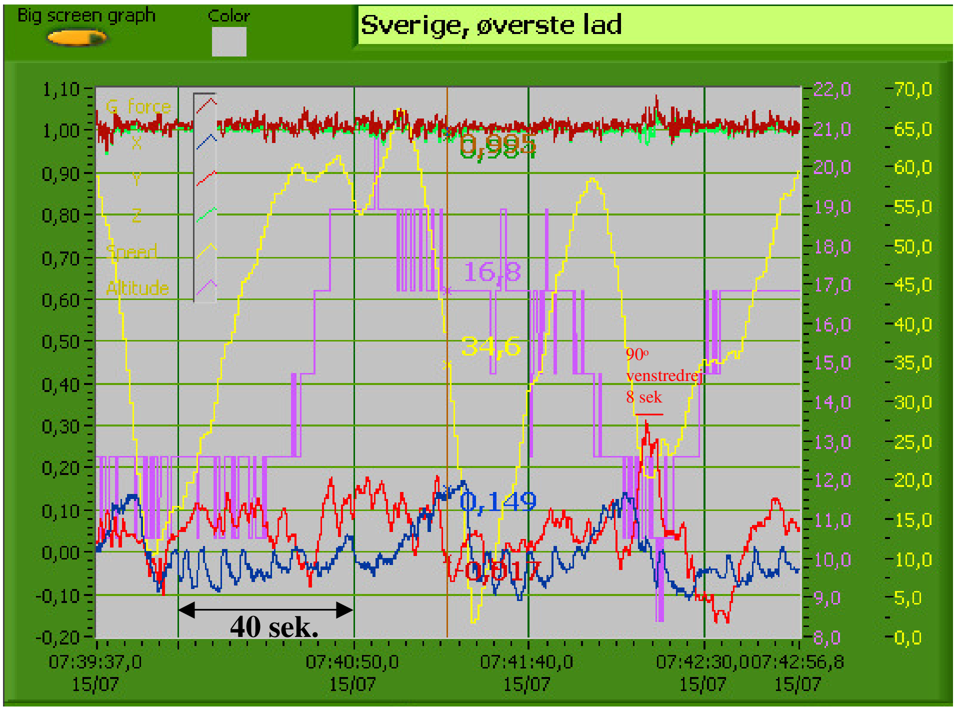


Figure 11U. Data from upper tier, "mixed transport" involving acceleration, decellation and turnings of up to 180°.

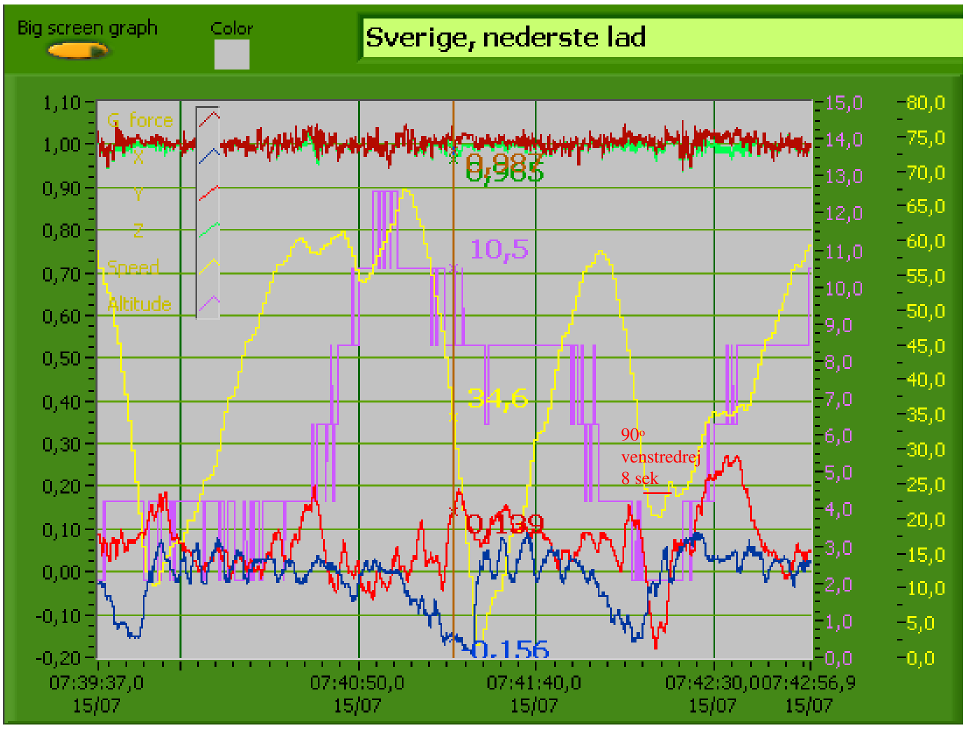


Figure 11L. Data from lower deck, "mixed transport" involving acceleration, decellation and turnings of up to 180°.

The blue curve on Figures 11U and 11L shows the numerical effect on the forward-return (X-axis) of up to 0.19 g (value without a pre-fix) at braking, resulting in decreasing speed (yellow curve). Acceleration during gear-change results in a rythmical swing on the blue curve (X-axis) numerical up to 0.11 g. Only marginal differences were registered between the two tiers.

The red curve shows the sideways effect (Y) with numerical values up to 0.32 g on the upper tier and 0.27 g on the lower tier. These swings were a result of the horizontal movement of the vehicle (turnings). There were frequent registrations of differences between the two tiers, which could be because the tiers heeled over in different degrees. This phenomenon will be further investigated at a later date.

The green curve gives an effect on the vertical level (up-down). When the vehicle is at a complete stand still and is 100% in horizontal position the values will always be 1g, which is equal to the gravity of the earth. When the vehicle hits a bump on the road it is reflected on the vertical axis, which will register the bump as a deviation from 1g. In the section illustrating the transport the reflects were up to 0.06, and no serious difference was registered between the two tiers.

The lilac curve (height above sea level) discloses whether the vehicle is driving on a road with a rise or a fall. We can see that the biggest rise was imediately before 7:40:50 hours where the height rose som 7 meters in the course of 10 seconds. As the vehicle was driving at a speed of appox. 60 km/h at that time it can be converted to a rise of approx. 3.8%. A rise not higher than this is expected to have only marginal effect on the balance of the pigs. It is, however, evident that the pigs will be more unstable during braking of the vehicle while driving downhill compared to a similar situation driving uphill.

pH- and temperature measurements

During the 4 days investigation the outdoor temperatures were relatively low for the season (July/August), and the effect of the mechanical ventilation is thus only small since it does not start up until the temperature in the compartment reaches 20°C.

pH1 is measured shortly after debleeding and shows indirectly the amount of lactic acid accummulated in the muscles. The measurement thus gives a hint of the physical load on the pigs and/or a possible increased adrenalin level. Since the pigs were slaughtered shortly after arrival at the abattoir the measurement also gives a picture of the situation as it was on the vehicle.

T-test, Table 10, illustrates differences between treatments with or without mechanical ventilation, as follows:

- [1] Variations in temperatures on the upper tier are the same, the average temperature difference is 3* significant (Pr > │t│0.0007) different from the average, see Table 10.
- The variation and the average of the temperature on the lower tier are alike
- The variation and the average of outdoor temperatures are alike
- [2] The variation of pH_1 is different, yet not significant. The avarages are alike. The pH_1 level is normal.

Kristianstad	Treatment							
	Without ventilation				With ventilation			
	Ave.	std	min	max	Ave.	std	min	Max
Temperature upper tier	[1]12.4	1.9	9.4	18.0	[1]14.9	1.3	12.5	17.7
Temperature lower tier	18.7	2.0	16.3	22.4	19.0	2.0	16.9	23.6
Outdoor temperature	14.5	0.5	14.0	15.0	14.5	0.5	14.0	15.0
pH_1 ave. per compartment	6.5	[2]0.1	6.4	6.6	6.5	[2]0.0	6.5	6.6

Table 10. Temperature and pH
The table shows no significant difference in pH_1 level. There may be significant differences with respect to temperatures in compartments at temperatures below 20^{o}C.

Conclusions and recommendations

Animal welfare

In the light of transport times and temperatures registered in this investigation we can conclude that no conditions or clinical symptoms have been observed that have affected good animal welfare negatively. Good animal welfare has prevailed down to temperatures of minus 5^{o}C.

In connection with offloading, the wellbeing of the animals was checked. During this veterinary check, the animals did not display any symptoms of reduced wellbeing. Neither were found skin damages like signs of congelation or similar. It was observed though, that the animals lied more close together compared to transports in the summer. By doing so, the pigs have compensated for the lower temperatures during the transport.

The transport vehicle and in particular the compartments have been designed for lower temperatures having double walls and insulation between the walls, as mentioned in the present report.

It should furthermore be considered that temperatures measured among the pigs are considerably higher compared to the temperature in the open room where the measurement equipment is placed. This investigation measured even lower temperatures compared to the actual temperature between the pigs.

The argument above supports the fact that pigs may very well compensate for temperatures down to minus 5-10^{o}C during transports of up to 8 hours or even longer.

During the recent 20-30 years there have been an official veterinary check when offloading pigs at the abattoir, and during this time of period there have been rather few comments/reports on animals that have been transported in cold weather.

Since 1998 there have in addition within the company's own control program been carried out current control in relation to animal welfare, specifically via the ethical audit. The ethical audit evaluates animal welfare and conditions during transport and offloading as well as during stunning and debleeding. This audit has had no comments or registration of deviations attached animals having been transported at low temperatures.

Times for loading and offloading

It was not unusual that the haulier who drove the test vehicle used 50% or more of the transport time for loading of pigs onto the vehicle. In other countries with which we can compare 30-40% of the transport time was used for loading of pigs. This could be because of the size of the producer or better conditions.

In connection with stops and with pigs on the vehicle there is an increased risk of the compartments being heated and the CO_2-level increasing, as this investigation has demonstrated. Stops are considered being one of the most critical conditions in connection with normal transports and micro climatic conditions.

The reason why the rather long time spent on loading has not be further investigated.

Differences between the two test vehicles

The test vehicle has been constructed such that it makes allowances for the best possible ventilation and evenly distributed ventilation openings.

Ventilation openings have been distributed along the side of the truck body in its entire length. The mechanical ventilation has been placed in the same area. The test vehicle has furthermore a system for automatic start of the mechanical ventilation when the temperature reaches 20^{o}C or above and for continuous ventilation until the temperature gets below 20^{o}C. This construction will ensure that the temperature level is expected to get beyond 25-30^{o}C very seldom. The control vehicle has a more conventional construction. Its ventilation openings are at an absolute minimum compared to the legal demand of a minimum of 20% of the floor space. The ventilation openings have furthermore been built into the sides of the truck body in blocks resulting in uneven distribution of ventilation air. The control vehicle has mechanical ventilation that primarily serves the upper tier and only to a very limited extent the lower tier. The mechanical ventilation does not start up automatically in case of rising temperatures as does the ventilation in the test vehicle. Ventilation is to be started manually, and it is left to the driver to evaluate the temperature in the truck body.

Temperatures at stops and during transport

As demonstrated by the investigations there is a rather large rise in temperature when the vehicle is at a stand still compared to when the vehicle is running. A vehicle running does not cause any immediate problems with respect to temperatures because of a relatively large air change and considerable wind speed.

To ensure a lower temperature in the truck body it is necessary to have mechanical ventilation installed and to measure the temperature in the truck body in order to let the driver know when there is a need for ventilation. It is however better to have a control unit take care of start and stop of the mechanical ventilation, since there is a good chance that the driver forgets to do so.

If a control unit for start and stop of the ventilation as well as a meter for measuring temperature have been installed in the truck body it is relatively simple to log these measurements as documentation for the authorities and customers in case a need should arise.

Mechanical ventilation

At loading of pigs into the vehicle the mechanical ventilation provides a slow rise in temperature than the natural ventilation, 0.10^{o}C/minute vs. 0.21^{o}C/minute.

In connection with long lasting loadings of pigs the mechanical ventilation will provide a lasting drop of temperature in relation to natural ventilation that will keep on rising.

Mechanical ventilation contributes to the improvement of the micro climate in the truck body, particularly in connection with stops/loading of pigs onto the vehicle.

In connection with loading, the temperature in the two front lower compartments (1L and 2L) was 3.1^{o}C to 5.2^{o}C higher than in the other compartments of the vehicle. For longer stops/loadings this difference increased further with natural ventilation whereas the difference decreased with mechanical ventilation. This illustrated the effect of using mechanical ventilation.

The air humidity – when the vehicle was fully loaded at stops/loading – was with natural ventilation on average 97%. With mechanical ventilation the average was 82%. This shows that the mechanical ventilation helps bringing down the humidity in the truck body as well.

The concentration of carbon dioxide goes up very fast in vehicles standing still. To approx. 2000 ppm in vehicles with mechanical ventilation and to approx. 8000 ppm in vehicles without mechanical ventilation. Limits are normally set at max. 3000 ppm from a ventilation point of view and not from an animal welfare point of view. The carbon dioxide level in relation to good animal welfare is not knows nor has it been checked.

During transport the carbon dioxide concentration was 600-700 ppm both for mechanical as well as natural ventilation. This proves that the air circulation during transport and with the openings for natural ventilation is satisfactory.

Air movements were mapped out both in relation to stops/loading and transport. At stops/loading and use of mechanical ventilation it was demonstrated that the mechanically supplied flow of air made the air move, and the air was changed as intended except for in a few small areas in the truck body to which the air stream did not go.

The dimensioned ventilation output in the truck body was calculated nominally to be between 75 and 93m^3/h (100 to 125 kg live weight pigs). It is a condition though that the ventilation air is evenly distributed in the truck body (Christensen, L., 2003). The output calculated is presumed to be the amounts that should be used for the future dimensioning.

When putting up screens to protect pigs, it being grating, perforated plates or similar, it will affect the ventilation in the vehicle. This should be considered when designing ventilation openings. On the test vehicle the screening covered some 30% of the free space. This percentage should not be exceeded. According to present EU legislation it must be possible to adjust ventilation openings. This should not be done by closing some of the ventilation openings completely. It could be done by using sliding plates that only close in part, since it is also a demand by EU legislation that the ventilation should be evenly distributed over the compartments of the vehicle.

The ventilation openings should be placed along the sides of the truck body, in the full length of the vehicle and on each tier.

Randall (1996) claims that openings for supply of fresh air should have a height of 500 mm. Christensen (2003) claims that ventilation openings should have a nominal height of 300 mm to supply sufficient amounts of fresh air.

The area of natural ventilation openings should not be reduced by more than 30% of their nominal area, and they should be constructed such that the supply of fresh air is not reduced during transport.

J. Kraft furthermore concludes:

The main question of my investigation whether natural ventilation reduces the risk of stress because of heat on hot days, the answer is yes. This is in particular true during loading of pigs onto the transport vehicle and when the vehicle stands still. This conclusion is confirmed by other scientists, let me mention Kettlewell et al. (2001) and Christensen (2003).

Measurements of outdoor temperatures for this investigation were not quite fair because the temperature loggers had not been placed correctly. The outdoor temperatures used were temperatures informed by the SMHI. The temperature logger was placed under the vehicle, the purpose of this was to avoid it being exposed to rain and direct sunlight (correction by DMRI: This point of measuring has been substituted by an instrument for measuring temperature supplied and mounted by DMRI and does thus not affect the results of this report).

Another conclusion of my work is that it must be possible to perform measurements in individual compartments. Otherwise will the big time differences that the pigs were exposed to during the transport result in the varying temperatures in the individual compartments not providing sufficient relevant information. Temperature differences particularly during loading are thus important factors to include to get the correct picture of how the climate affects the pigs (correction DMRI: Since it appears from J. Kraft's results that compartments 1L and 2L are the hottest on the vehicle it should be sufficient to measure the temperature in one of these compartments only).

One of the minuses by using mechanical ventilation is the relatively high noise level on the vehicle, 75-81 dB(A). A remote control was therefore made to shut down the ventilation for 1-2 minutes just by pushing a button.

Mortality during transport

On the test vehicle the mortality rate was very low, and it is naturally difficult to make statistics when only 3 pigs died during transport. The difference was never the less big when the test vehicle was compared to the control vehicle and also when considering that the two vehicles have been run under similar climatic condition and have been carrying same number of pigs.

In cannot be doubted that the different construction of the ventilation openings as well as the difference in execution of the transport and use of mechanical ventilation have made large difference.

All future constructions should therefore follow the same principle with respect to ventilation as has been done for the test vehicle.

Measurement of vibrations

G-measurements showed that the test vehicle did not differ negatively from other similar two-tiered vehicles.

Differences were found with respect to influence by vibrations and load between the upper and lower tiers. However, during normal transports with pigs the negative and the positive conditions will counterbalance each other between the two tiers, and it can thus not unambiguously be evaluated whether one tier is actually better than the other. There is a tendency, however, towards low frequency vertical vibration occurring more often on the upper tier.

As already mentioned, the knowledge of the effect of vibrations on pigs is limited – apart from the fact that low frequency vibrations may arose car sickness.

pH measurements

pH_1-measurements showed that there were no significant differences between transports below 20^{o}C, even though there was a distinct difference in temperatures between the individual compartments on the vehicle.

Future work and recommendations

Supply of pigs

The prevalent conditions at loading of pigs should be investigated further. The present investigation has proved that time spent on loading the pigs onto the vehicle equalled the time spent on the actual transport of the pigs in many of the transports carried out.

In other countries that we can compare with, the time spent on the actual transport is around 60.-70% and the time spent on loading the pigs 30-40%. The time spent on loading of pigs is thus considerably shorter. There should be an economic profit in case the time for loading could be reduced. If the time for loading is reduced the risk of the truck body getting heating when standing still will be reduced as well.

Capacity

It was not a rare thing that the test vehicle did only one transport of pigs per day. The majority of the daily transports took between 2 and 4 hours and the transport vehicle might very well carry out two trips per day and thus make a saving. This should be further investigated.

Truck builder and vehicle construction

The conclusions of this report should be incorporated in the recommendation to truck builders given in the “Handbook for construction and use of pig transport vehicles (HST)”.

The Handbook should be reviewed with the aim to improve it in relation to construction of the test vehicle, but also in relation to construction of the tiers. The present vehicles have divided their tiers to correspond to each compartment. They comprise more mobile units and the requirement for mobile units should be looked into, since mobile units are more expensive than a vehicle with mobile tiers and floor space equal to the floor space of the entire truck body.

It should be considered to divided the present Handbook into two main sections: “Construction” and “Use”.

Measurement of vibrations

It should be looked into whether tiers hung in wires are different from tiers hung with cylinders in relation to vibrations.

Participants

Swedish Meats: Roland Andreason, Karin Johnson and Britt-Marie Möller. Agricultural University of Sweden. Krister Sällvik and Jannica Kraft (4 days test).

DMRI: Flemming Nøddegaard, Lars O. Blaabjerg, Peter Vorup, Maiken Baltzer and Mianne Darré.

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Attachment 1

2. 4 days test

Agricultural University of Sweden

Per request from Swedish Meats the Agricultural University of Sweden, Institute for agricultural bio systems and technology, participated in this part of the project. The participants were Professor Krister Sällvik and student at the University Jannica Kraft. In connection with her thesis work Ms Kraft has described in detail the investigations (Kraft, J., 2005), why only the most essential results and additional results that are not part of her project will be reviewed in this section on the "4 days tst".

In the report has been included extracts from Ms Kraft's report in Swedish and with the comment "Correction DMRI" where we do not agree with her conclusions.

Most important results

Natural ventilation

A typical course of air temperature and relative humidity during loading of pigs, transport and offloading is illustrated I Figure 12. The temperature rises with some 12°C during loading. The relative humidity rises very quickly to 100%. When the transport vehicle starts the temperature drops some 5°C and the relative humidity approx. 25% and then it stabilizes. When the vehicle arrives at the abattoir, the air temperature and the relative humidity rise.

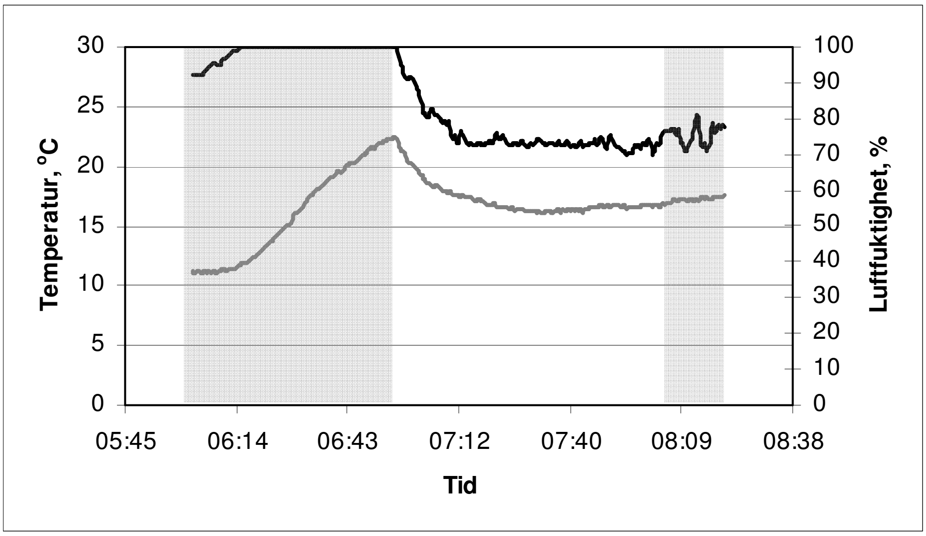

Figure 12 – Air temperature and relative humidity on a vehicle with natural ventilation.
Black line = relative humidity

Concentration of carbon dioxide follows the same pattern as do the temperature and the relative humidity. During loading the concentration rises fast. On the upper tier the concentration rises to 8000 ppm which is max. value measured. The concentration is between 3000 and 4500 ppm on the lower tier. When the vehicle starts running the concentration of carbon dioxide falls to 600-700 ppm on the upper as well as the lower tier. When the vehicle is standing still at the abattoir the concentration rises again, somewhat fast on the upper tier than on the lower tier, see Figure 13.

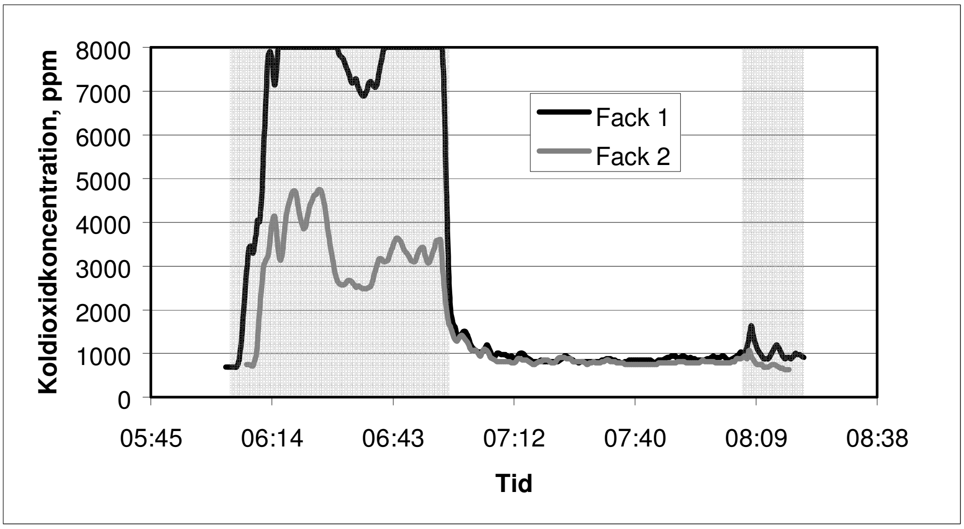

Figure 13 – Concentration of carbon dioxide on the vehicle with natural ventilation. Fack 1 = 1U and Fack 2 = 1L

The carbon dioxide concentration is somewhat higher on the upper level than on the lower tier.

Mechanical ventilation

Temperature, relative humidity and carbon dioxide

A typical course of air temperature and relative humidity during loading of pigs, transport and offloading is illustrated I Figure 14. The temperature goes up slowly with some 10°C during loading. The relative humidity rises very quickly to 90%during loading and then goes down again somewhat once the ventilation starts. When the vehicle starts running the temperature and the relative humidity go down a bit and become more stable. When the vehicle arrives at the abattoir, the air temperature and the relative humidity rise.

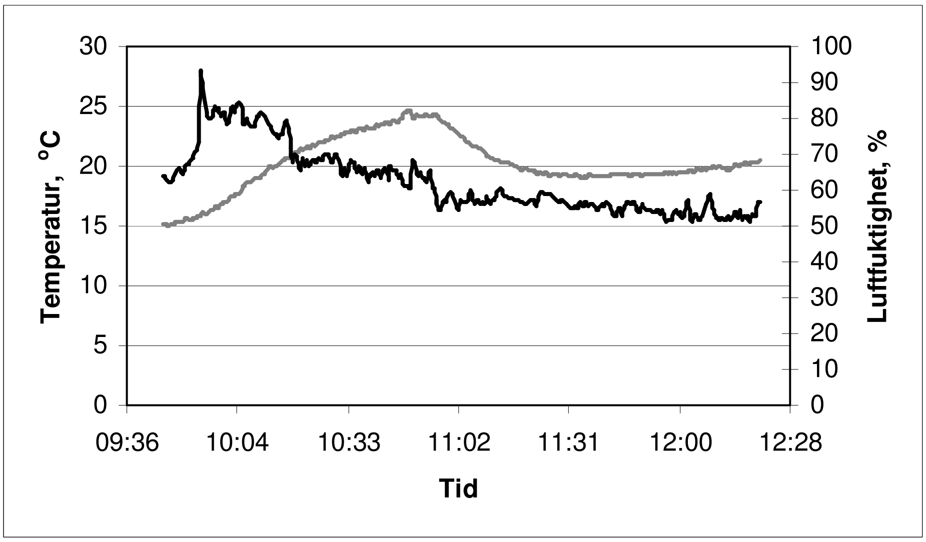

Figure 14 – Air temperature and relative humidity in the vehicle with mechanical ventilation.
Black line = relative humidity. ↑ shows where the ventilation starts.

The carbon dioxide concentration follows the same pattern as the temperature and the relative humidity. When loading the concentration rises fast. On the upper tier the concentration rises to a level which is some 2500 ppm higher (Correction DMRI: 1000 and not 2500, reference Figure 15) than on the lower tier. When the ventilation starts the carbon dioxide concentration drops to just below 2000 ppm on the upper as well as the lower tier. During transport the carbon dioxide concentration drops further to 600-700 ppm on both tiers, reference Figure 14. When the vehicle arrives at the abattoir the concentration rises again, faster on the upper tier than on the lower tier.

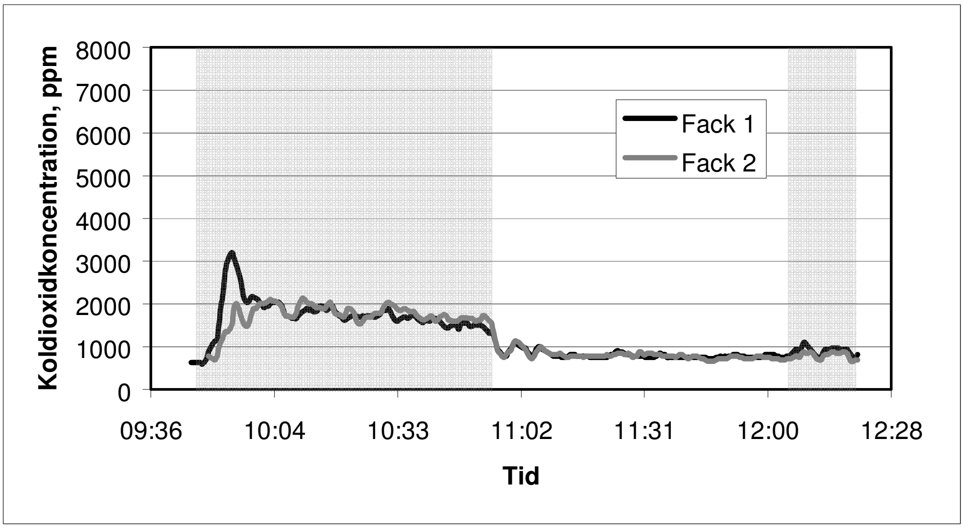

Figure 15 – Carbon dioxide concentration on the vehicle with mechanical ventilation.
↑ indicates when the ventilation starts.
Fack 1 = 1U and Fack 2 = 1L

The carbon dioxide concentration is somewhat higher on the upper tier than on the lower tier. The difference decreases however, when the ventilation starts up (Correction DMRI: The difference is counterbalanced when the mechanical ventilation starts up, refer Figure 15).

Temperature at loading and when standing still

This investigation confirms the problems with rising and high temperatures when a vehicle is standing still. The temperatures in the truck body rise both with natural as well as with mechanical ventilation. The temperature rises more slowly and levels out faster with mechanical ventilation. The disadvantage of mechanical ventilation is, however, that it is noisy.

The difference in temperature within the transport vehicle as well as outside the vehicle increases more with natural ventilation than with mechanical ventilation. With mechanical the temperatures further rises more slowly.

The result shows that the temperature during loading rises faster and to a higher temperature with natural ventilation than with mechanical ventilation. The temperature may rise by 0.21°C/minute in a fully loaded vehicle that stands still and has natural ventilation, and when the air velocity is low. This means that the temperature in a fully loaded vehicle that stands still for 30 minutes may go up from 20°C to more than 26°C. In a vehicle with mechanical ventilation, the temperature will go up by 0.10°C/minute. This will cause the temperature in a fully loaded vehicle that stands still for 30 minutes to go up from 20 to 23°C. It is thus substantiated that mechanical ventilation improves the thermal environment of the pigs during loading as well as when in a fully loaded vehicle that stands still.

Temperature during transport

For transport in vehicles with natural as well as in vehicles with mechanical ventilation, the temperature will go down and become more stable during the actual transport than during loading and when the vehicle is standing still. The temperature differences increased between the tiers and was somewhat higher on the lower tier. The differences decreased marginally - compared to when loading the vehicle – between the front and the back of the vehicle.

Relative humidity

Measurements show that the relative humidity was on average 97% in case of the fully loaded vehicle standing still and with natural ventilation. In case of a vehicle with mechanical ventilation the corresponding average was 82%. It proves that ventilation helps removing humidity from the vehicle.

According to Randall (1993) the relative humidity is not important to pigs when the temperature is below 30°C. In general the relative humidity may rise to 95% without causing problems on the pigs- Sällvik et al. (2004) proved that stress in pigs because of heat will increase already at a relative humidity of 80% and at temperatures above 21°C.

Scientists have agreed that a high relative humidity at high temperatures constitutes a risk to the wellbeing of pigs. Differences of opinion in relation to which degrees of relative humidity and which temperatures can be considered acceptable respectively damaging to pigs are remarkably big. As long as the differences of opinion exist, it seems wise to stick to the information given by Sällvik et al and be cautious when evaluating the risks of stress because of heat.

Carbon Dioxide

The carbon dioxide concentration rises fast during loading onto vehicles with natural or mechanical ventilation. When the vehicle is fully loaded and stands still, measurements from the roof of the vehicle show 8000 ppm with natural ventilation. In vehicles with mechanical ventilation the value was 5000 ppm (Correction DMRI: 3000 ppm reference Figure 15). This proves that the airflow is considerably bigger with mechanical ventilation than with natural ventilation. According to Randall (1993) the carbon dioxide concentration should no bigger than 3000 ppm with minimum ventilation.

Airflow

When the vehicle was standing still and with mechanical ventilation in use, it was substantiated that the mechanical ventilation system really activated the airflow. Only small differences were observed in the airflow between the different compartments on the tiers, yet there were big differences between the individual tiers. Certain small areas in the compartment found shelter and could not be reached by the airflow from the air ducts.

The calculation of the airflow based on calculations of the heat balance seemed reliable. There was a distinct difference between natural and mechanical ventilation when the vehicle was fully loaded and standing still.

Carbon dioxide concentration was measured only in compartment 1 and 2. The intention was that the average value for these two compartments should serve as average for the entire vehicle. The differences between the two compartments were however distinct. This indicated that there would be differences between all compartments on the vehicle. Measurement of the carbon dioxide concentration in all compartments would have given a more reliable result.

Despite the fact that the result in general shows the same clear tendency, the airflow is considerably higher (approx. 3 ggr) in vehicles with mechanical ventilation compared to vehicles with natural ventilation, both fully loaded and standing still.

With mechanic ventilation the measurements did not reach max. 5000 ppm., but was above maximum when there were no mechanic ventilation, reference Figure 13 and 15.

Times for loading

An important result of this work is the demonstration of the importance of the time used for loading. This investigation concludes that times spent on loading of pigs vary considerably between the various producers (refer table 8). According to Swedish Meats recommendations it is the responsibility of the producers to take care that pigs for slaughter should be graded and marked to facilitate loading onto the vehicles. The situation is like that most of the times. It does happen though that grading and marking of pigs only commences when the vehicle is ready to receive the pigs.

Times for loading varied much between the various producers. To load 110 animals onto the vehicle took between 19 and 94 minutes. To load between 75 and 78 animals onto the hanger took between 15 and 55 minutes. Whether the transport starts from one farm only, and whether the producer carries out the loading at a slow pace equal to the longest times for loading pigs onto the vehicle and the hanger, it means that the first group of pigs (loaded into compartment 1) has to stand on the vehicle for more than two hours before the vehicle takes off.

Because of the big variation in times for loading, it is only reasonable to judge that the producers do not consider the wellbeing of pigs to any high degree. It would be desirable if Swedish Meats informed the producers of the purpose of their general guidelines and of the consequences when not following these guidelines. Similar thoughts have been expressed by Mr Jan Kristoffersson, veterinarian (1994).

Sällvik et al. (2004) and Christensen and Barton Gade (1995) have demonstrated that the thermal environment of the pigs is most critical in the front compartment on the lower tier. In as much as this compartment is loaded first, the animals in that compartment are also the ones the most exposed. Even this report confirms that the thermal environment for pigs is the worst in the front compartment on the lower tier.

Offloading took between 3 and 8 minutes and was well organised by the abattoir. The short time and the fact that the offloading ramp was open in the total width of the vehicle (approx. 2.45 m) resulted in no rise in temperature.

Advantages of mechanical openings

The result proves that mechanical ventilation has a positive effect on the environment in the compartments as far as temperature, relative humidity and carbon dioxide concentration are concerned. It is above all when a vehicle is standing still or driving at low speed that the openings prove their justification. It is when these items constitute the majority of the total transport that the ventilation openings prove their justification.

Although the outdoor temperatures during these measurements were abnormal for the month of July, the ventilation openings proved positive. It could be assumed that higher outdoor temperatures might have given further proof to confirm the differences between natural and mechanical ventilation, to the advantage of mechanical ventilation. The advantages overshadow the disadvantages of the high noise level. The high noise level is a problem that should be improved by means of better technique. Maybe even placing of the ventilation openings could be changed to relieve the problem with the differences in temperature between the front and the back of the car.