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Transport temperatures observed during the commercial transportation of animals

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Summary

Current temperature standards and those proposed by the European Food Safety Authority (EFSA) were compared with the actual practices of commercial transport in the European Union. Temperature and humidity records recorded for a year on 21 vehicles over 905 journeys were analysed. Differences in temperature and humidity recorded by sensors at four different positions in the vehicles exceeded 10°C between the highest and lowest temperatures in nearly 7% of cases. The number and position of temperature sensors are important to ensure the correct representation of temperature conditions in the different parts of a vehicle. For all journeys and all animal categories, a relatively high percentage of beyond threshold temperatures can be observed in relation to the temperature limits of 30°C and 5°C. Most recorded temperature values lie within the accepted tolerance of ±5°C stipulated in European Community Regulation (EC) 1/2005. The temperature thresholds proposed by EFSA would result in a higher percentage of non-compliant conditions which are more pronounced at the lower threshold, compared to the thresholds laid down in Regulation (EC) 1/2005. With respect to the different animal categories, the non-compliant temperature occurrences were more frequent in pigs and sheep, in particular with regard to the thresholds proposed by EFSA.

Keywords

Animal, European Union, Humidity, Livestock, Regulation, Temperature, Temperature humidity index, Threshold, Transport.

Temperature di trasporto osservate durante viaggi commerciali di animali

Riassunto

Gli attuali standard adottati dall'UE riguardanti le temperature di trasporto degli animali e quelli proposti dalle opinioni scientifiche dell'EFSA (Autorità Europea per la Sicurezza Alimentare) sono stati confrontati con le reali condizioni di trasporto commerciale nell'Unione Europea. Lo studio ha analizzato le informazioni di temperatura ed umidità provenienti da oltre un anno di trasporti animali, eseguiti da 21 veicoli e relative a 905 viaggi. Le differenze in temperatura ed umidità registrate da sensori posizionati in 4 punti diversi dei veicoli hanno oltrepassato 10°C tra temperatura minima e massima in quasi il 7% dei casi. Il numero ed il posizionamento dei sensori sono aspetti importanti per rappresentare correttamente le condizioni termiche nelle differenti parti del veicolo. In linea generale, in tutti i viaggi ed in tutte le categorie animali oggetto dello studio è stata osservata una percentuale relativamente alta di valori eccedenti i limiti di 30 e 5 gradi. Molte delle temperature registrate ricadono all'interno della tolleranza di ±5°C prevista dal Regolamento (EC) 1/2005. I limiti di temperature proposti da EFSA determinerebbero in generale una più ampia percentuale di non conformità se confrontata ai limiti previsti dal Regolamento (EC) 1/2005, più pronunciata relativamente al limite inferiore. Per quanto riguarda le diverse categorie di animali trasportati le non conformità sono state osservate più frequentemente nel trasporto di suini ed in quello di pecore, soprattutto se si applicano gli standard proposti da EFSA.

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Parole chiave
Animali, Bestiame, Indice, Umidità, Regolamento, Temperatura, Unione Europea.

Introduction

Temperature standards have been applied in the European Union (EU) to the long-distance transportation of horses, cattle, pigs, sheep and goats since 1998 and the same temperature range of 5°C to 30°C with a ± 5°C tolerance is still currently applicable (6, 9).

Two scientific opinions from the European Food Safety Authority (EFSA) on temperature standards for the transport of animals propose different temperature ranges in regard to different categories of animals (7, 8). In response to the EFSA proposals, studies have examined the effects of ventilation in vehicles to ensure acceptable temperature ranges, measured stress parameters in animals during transport and attempts have been made to understand the factors that influence body temperature during transport (1, 2, 3, 11, 12, 13, 14, 16, 17, 18).

Temperatures during transport are influenced by a complex interaction of external factors, such as seasonality, time of day, meteorological and geographic conditions which make it difficult to give a comprehensive picture of all possible transport conditions along the animal transport routes within the EU. The present study provides a broad picture of the temperatures that occur in routine commercial transportation of pigs, cattle, sheep, goats and slaughter horses along the principal trade routes in Europe and it also evaluates the level of non-compliance in respect of the thresholds given in the current legislation (6, 9) and proposed by EFSA on standards for the micro-climate within animal transport road vehicles (7, 8).

According to this information: 60% of all pigs in intra-EU trade were transported from Denmark and the Netherlands to Germany, Spain, Italy and Poland and 36% of all cattle in intra-EU trade were transported from France and Poland to Italy and Spain. According to the Food and Veterinary Office (FVO) of the European Commission, an important flow of cattle was also reported from the EU (mainly from France and Germany) to countries east of Europe (mainly Russia). The most significant transportation of sheep was seen from Hungary (18%) and Romania (22%) to Italy and Spain and from Spain (4%) to Italy, whereas approximately 75% of all goats were moved from the Netherlands to France and Spain. Regarding slaughter horses, most of the animals (52%) came from Poland, Romania and Bulgaria to Italy. In 2006, the EU trade control and expert system (TRACES, the information exchange system referred to in Article 20 of Directive 90/425/EEC) recorded the transportation, for 2006, of over 270 000 animals (55% cattle, 33% pigs, 7% horses, 5% sheep, <1% goats) with over 31 million animals (68% pigs, 19% cattle, 12% sheep, 1% horses and goats).

Materials and methods

On the basis of data for 2006 from TRACES and information from the FVO, the principal trade flows of pigs, cattle, sheep, goats and slaughter horses in imports into and exports from the EU were identified.

As different trade patterns occur for different categories of livestock, the species included in the study were broken down into the following categories:

- pigs up to 30 kg live weight
- pigs over 30 kg
- cattle up to 6 months of age
- cattle above 6 months
- sheep up to six months of age
- sheep over 6 months
- horses and goats.

To obtain a broad picture of the commercial transportation of these animal categories, transporters operating regularly along the trade routes identified were invited to participate for approximately 12 months with one vehicle for each of the most frequented trade flows and for each of the above animal categories. Ten companies from 5 member states volunteered with 21 transport units (9 trucks with trailers and 12 semi-trailers), on the basis of the most frequent transportation along the principal trade routes.

With the exception of goats and slaughter horses, each participating vehicle travelled a number of different trade routes. Therefore, for each animal category, the most frequented trade flows were covered by more than one vehicle.

The fleet of participating vehicles that represented seven major brands of animal transport vehicle manufacturers in Europe, were built between 1993 and 2007, and all were equipped with mechanical ventilation, a light-coloured roof and, with the exception of 3 semi-trailers, all had an insulated roof and none had a misting system.

All trucks and semi-trailers were equipped with data loggers with integrated temperature and humidity sensors (HOBO Pro v2 U23-001) set to record temperatures and humidity at 15-min intervals over the entire data collection period from February 2008 until March 2009, irrespective of the presence or absence of animals in the vehicles. The calibrated temperature sensors had a resolution of 0.02°C, an accuracy of 0.2°C over 0°C-50°C and the humidity sensors a resolution of 0.03% and an accuracy rate of ±2.5%. Regarding the location of the data loggers/sensors, the following scheme was applied as shown in Figures 1 and 2:

- in vehicles with one floor (mono-volume), 1 median was placed in the front and 1 lateral in the back, both situated approximately 1 m above the floor, 1 median was placed in the front and 1 lateral in the back, both close to or beneath the roof
- in multi-tier vehicles, 1 median was placed in the front and 1 lateral in the back, both on the ceiling of the lowest tier, 1 median was placed in the front and 1 lateral in the back, both close to or beneath the roof
- one data logger was placed under the vehicle and was protected from direct sunlight and the motor of the towing vehicle.

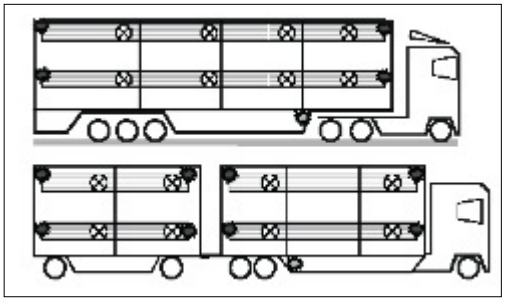

Figure 1
Installation of sensors in a semi-trailer and in a truck and trailer
Outside sensor in light grey and inside sensor in dark grey
Inside sensors were placed under the ceiling of the lowest tier and under the roof, in front in the middle and in the back, close to the side wall opposite the mechanical ventilation

In addition, in two trailers that transported pigs, data loggers were installed in the above-listed locations. No sensor inside the vehicles was located directly in the flow of a mechanical ventilator. The sensors were placed at a distance of approximately 15 cm-20 cm from the front or back side of the animal compartment, respectively, and at a distance of

Figure 2
Example of a sensor installed inside in the front of the animal compartment on the ceiling of the lowest tier with protecting cage open (left) and outside, under a semi-trailer (right)

approximately 3 cm to the underlying metal wall.

Of the 113 devices initially installed, 13 had to be replaced during the study, five due to recording failure, five due to low battery charge after the winter, one damaged by animals and two were lost when the vehicle chassis was replaced. Three of the vehicles that participated originally were replaced by other vehicles and two vehicles only participated until mid-October 2008.

To identify the periods in which animals were on board during each individual journey, the category and number of animals loaded, starts, rests and completion of journey were extracted from the completed journey log which has to be filled in by the transporter for each journey that exceeds 8 h. For the purposes of the study, a journey is considered to be the entire transport operation with animals on board from the place of departure to the place of destination, including any rest that might occur at stops along the way.

The number of animals loaded was obtained for each journey. However, without having more specific information on how the load was distributed within the vehicles, a correlation between loading density and temperatures measured in the different parts of the vehicle could not be established.

Statistical analysis of the data was performed using the statistical software R© (The R Foundation for Statistical Computing in Vienna). Correlations were calculated using the Pearson product-moment correlation coefficient. Scatter plots with frequency distributions were obtained using the Using R© package (John Verzani, 2001-2002).

Results

Data downloaded from the vehicles provided a total of 3 861 606 records of temperature and humidity, registered at 15 min intervals by the 4 sensors inside and the one outside the vehicle.

According to the journey logs, of the data downloaded, 512 629 records pertained to 905 journeys with a total of nearly 325 000 animals. Table I gives the distribution of journeys and the number of animals transported by category of animals and by month.

Table I
Animal journeys recorded for participating vehicles by animal category and month

Species	2008											2009			Total	No. of animals (1 000)
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar		
Bovines ≤6 m	2	8	9	9	5	4	5	6	4	3	6	5	3	6	75	10.6
Bovines >6 m	11	7	18	10	9	13	8	21	32	19	15	15	16	13	207	7.9
Goats	2		1					1					3		7	4.9
Horses	6	3	4	4	4	7	6	8	10	7	4	8	6	4	81	1.4
Other*	1														1	0.0
Pigs ≤30 kg	16	12	22	28	13	28	22	28	25	19	18	23	21	10	285	214.7
Pigs >30 kg	21	18	4	15	18	15	10	11	7	14	17	16	7	4	177	39.0
Sheep ≤6 m	3	9	3	4		3	3	2	5	6	14	3	2		57	39.6
Sheep 6 m			3		1	4	2	1		2		1	1		15	6.6
Total	62	57	64	70	50	74	56	78	83	70	74	71	59	37	905	324.7

* one shipment of 31 alpacas

m months

Of the 905 journeys:

- approximately 70% of the journeys recorded involved the transportation of pigs along the main routes from Denmark and the Netherlands to Germany, Italy, Spain and Poland
- 70% of the recorded cattle journeys followed the routes from France, Germany and Poland to Italy, Spain and to countries in Eastern Europe and beyond
- 70% of the sheep transports recorded were along the routes from Hungary, Romania to Italy and Spain, or from Spain to Italy
- 63% of the horse transports recorded covered the main routes from Poland, Romania and Bulgaria to Italy.

A total of 25 of the 905 journeys included ferry transport, e.g. transports to Greece or from the United Kingdom to continental Europe.

In regard to the duration of the journeys, 8% lasted for over 3 days, 31% from 1 to 3 days, 47% between 8 h and 24 h and 14% less than 8 h.

Temperature and humidity variations

The temperature recorded by the different sensors on each vehicle showed variations which may not only be determined by daily and seasonal cycles but also by different climatic conditions encountered during the journeys, by the presence of the animals, by the circulation of air induced by the movement of the vehicle and by the possible use of mechanical ventilation. Figure 3 gives an example of temperature variations for the different sensors on a vehicle examined during a single period of one week.

The example reveals that at least two patterns emerge, namely: an increase in temperatures, especially in the front lower part of the vehicle, during the animal journeys and the increase in temperatures recorded by the sensors in the upper tier during the central hours of the day.

At the same time, there are large differences in the internal temperatures depending on the position of the sensors. Analysing the entire set of recordings the average difference between the maximum and minimum temperatures recorded by the four sensors inside the vehicles at a given moment was 3.5°C. In 7.3% of cases, differences were greater than 10°C and 50% of differences were distributed between 0.9°C and 4.4°C. Figure 4 shows the distribution of the differences by hour of the day, indicating that these differences tend to increase in the central hours of the day.

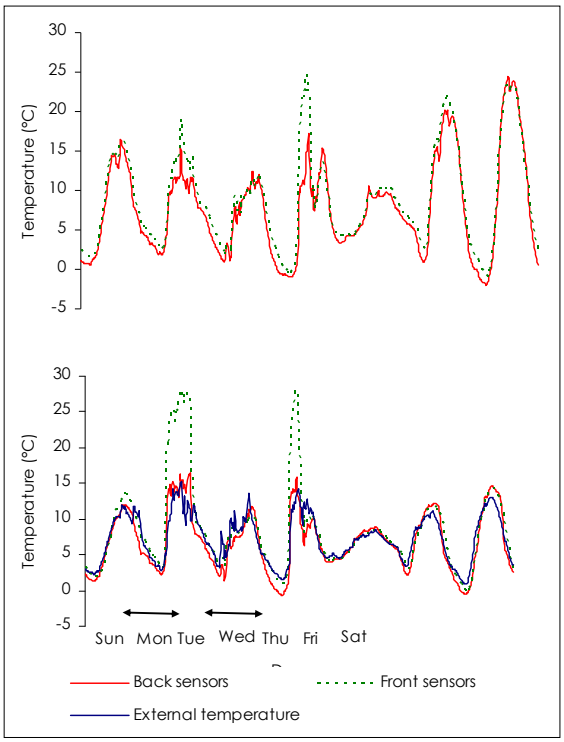

Figure 3
Example of temperature variations in a semi-trailer for one week, from 13 to 19 April 2008 on routes between Denmark and Germany)
Upper tier (upper chart) and in the lower tier (lower chart)
Horizontal arrows indicate the periods with animals on board

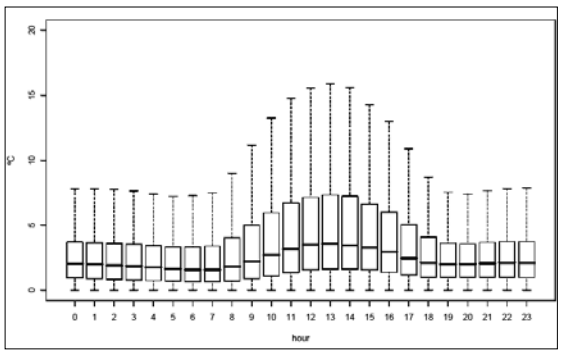

Figure 4
Differences between maximum and minimum temperatures recorded inside the vehicles by time of day with whiskers extending at 1.5 of the inter-quartile range

Correlations among temperature records in the different positions of each vehicle are given in Table II which shows that temperatures in the front and back of the same tier showed a similar stronger correlation, whereas weaker correlations were found between the front lower and back upper tiers, and between the front lower and front upper tiers. Correlations tended to be stronger in mono-volume vehicles, such as those used for transporting horses, rather than in multi-tier vehicles.

Table II
Correlation coefficients between temperatures recorded at different positions of the sensors in multi-tier semi-trailers during animal journeys

Sensor position	Back down	Back up	Front down	Front up
Back down	1.00			
Back up	0.92	1.00		
Front down	0.95	0.87	1.00	
Front up	0.93	0.99	0.89	1.00

Changes in the average of temperatures by time show a clear pattern of sinusoidal variation depending on the hour of day (Fig. 5).

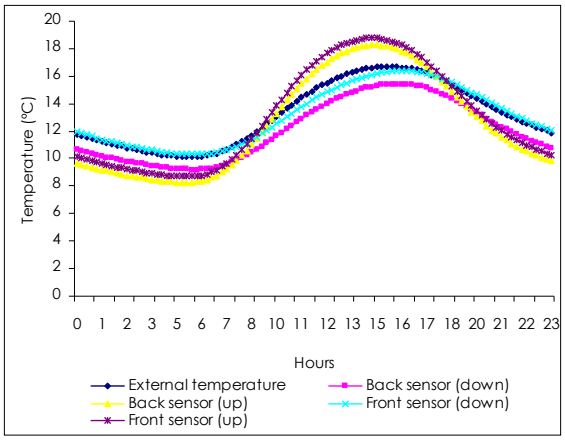

Figure 5
Average temperatures recorded on all vehicles during the duration of the study by time of the day and sensor position

To some extent, the internal temperatures follow the same sinusoidal behaviour of the temperature of the external sensor with a time shift and an amplified effect for the upper tier. Despite an insulated roof present in most of the vehicles, the temperature in the upper tier in the middle of the day rose in comparison to the lower tier and that recorded outside. This effect was reversed at night when the temperature in the lower tier became equal or slightly higher than the temperature of the upper tier. In general, the temperatures in the lower tier tended to be lower than the temperatures on the exterior.

An examination of the weekly variations of temperature showed that the difference between the upper and lower tiers were more pronounced on Saturdays and Sundays when the vehicle was more likely to be stationary. During the week and during animal journeys, the movement of the vehicle mitigates the effects of solar radiation and produces a cooling effect in the back of the upper tier if compared to the front tiers.

The presence of animals creates an increase in temperatures in particular in the less aerated front lower part of the vehicle. This effect is obvious during the winter and at night. On the contrary, as seen in Figure 6, in summer and with temperatures exceeding 20°C, the presence of the does not causing an additional increase in temperature among the front sensors of the lower tier compared to the exterior. This effect is more pronounced in pigs under 30 kg live weight. In bovines and sheep ≤6 months of age, this effect was less marked. In sheep and bovines >6 months of age, the average temperature in the front lower part of the vehicle was lower than the external temperature.

Humidity values were mainly distributed within the range of 60% and 90%. Except for the external sensor, there were no high differences in humidity values in the different parts of the vehicle. One effect produced by the movement of the vehicle is that the humidity decreased on all sensors. In general, there was a negative correlation between temperature and humidity. The negative correlation was stronger in the sensor in the upper tier where the most significant temperature fluctuations were also recorded.

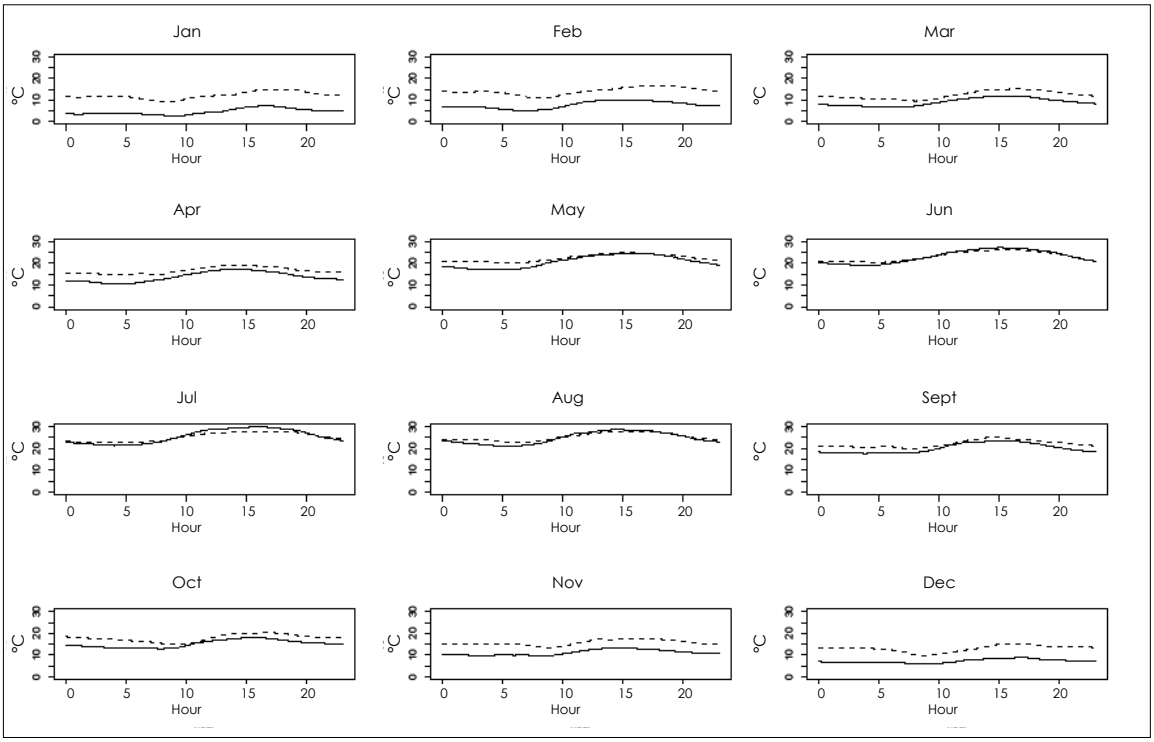

Figure 6
Average temperatures recorded during animal journeys by the front-lower sensor (dotted line) compared to the temperature recorded by the external sensor (normal line) by month and time of day

Impact of temperature thresholds

The temperatures recorded during the 905 animal journeys for all animal categories were compared with the temperature standards in force (5°C-30°C with ±5°C tolerance for horses, cattle, pigs, sheep and goats) and with the standards proposed in the EFSA scientific opinions as listed in Table III. Thresholds for pigs ≤10 kg and cattle ≤2 weeks are not shown as no animal journeys for these categories were recorded. In commercial transport, the status 'full fleece' or 'shorn' is normally recorded, therefore the thresholds for 'full fleece' was applied in this study to sheep >6 months of age and the thresholds for 'shorn' to sheep ≤6 months of age, since the EFSA opinion (on microclimate in road transport vehicles) cites values for lambs similar to those proposed for shorn sheep (7). No EFSA thresholds were given for horses.

Table III
Acceptable temperature ranges for different species/categories of animals in force and recommended by the European Food Safety Authority

Species	Category	Recommended by EFSA		
		Min °C	Max °C	
			RH <80%	RH >80%
Pigs	≤30 kg	14	32	29
	>30 kg	10	25 (30)*	25 (30)*
Cattle	≤6 months	5	30	27
	>6 months	0	30	27
Sheep	Full fleece	0	28	25
	Shorn	10	32	29
Goats		6	30	27

EFSA European Food Safety Authority
RH relative humidity
* threshold applicable in the presence of mechanical ventilation and misting devices

After recording temperatures at 15 min-intervals, the data were analysed in terms of:

- number of journeys with at least one non-compliant temperature measured at least at one of the 4 internal sensors in the vehicle
- number of 15-min intervals non-compliant with the thresholds during a journey (non-compliant intervals not necessarily in consecutive sequence)
- duration of a journey during which the temperature recorded by at least one of the 4 internal sensors of the vehicle was non-compliant with the temperature thresholds.

Table IV summarises, for all journeys and all animal categories, the percentage of journeys with at least one non-compliant temperature occurrence, the average number of non-compliant records during non-compliant journeys and the percentage of journey times where the non-compliant occurrence was observed.

Impact of high temperature thresholds

When considering a threshold of 35°C, 8% of journeys had at least one non-compliant event and, on average, each non-compliant journey had 11 non-compliant incidents. In 36% of the journeys for all animal categories, there was at least one occurrence of temperatures exceeding the 30°C limit and, on average, each of those journeys had 18 occurrences of temperatures above the 30°C limit. In the case of the EFSA limit (Table III), in 40% of journeys there was at least one non-compliant event and on average each non-compliant journey had 23 non-compliant occurrences.

In regard to the non-compliant journey times during the 905 journeys, the maximum temperatures within the vehicle exceeded the limit of 35°C in 1% of the journey times, the limit of 30°C was exceeded in 6% of journey times and the limits proposed by EFSA were exceed in 8% of journey times (7% of cases where humidity was below 80% and 1% with humidity above 80%). These percentages were calculated as the sum of records when the temperature from at least one of the internal sensors exceeded the threshold, divided by the total number of records during animal journeys in the entire observation period (102 128 intervals of 15 min).

As shown in Figure 7 which covers all animal categories, most non-compliant occurrences were recorded between May and September. In July, the level reached 23% of journey time for the 30°C limit and 27% for the EFSA limits.

Table IV
Temperatures recorded over the thresholds in force and in relation to limits proposed by the European Food Safety Authority

Temperatures over the thresholds	Journeys with at least one case of occurrence over the threshold (%)	Average number of occurrences over the threshold per journey	Journey time in which the threshold was exceeded (%)
Against high temperature thresholds			
35°C	8%	11	1%
30°C	36%	18	6%
EFSA*	40%	23	8%
EFSA ≥2 h**	17%	6	6%
Against low temperature thresholds			
0°C	17%	21	3%
5°C	46%	42	18%
EFSA*	58%	51	26%
EFSA ≥2 h**	44%	26	23%

EFSA European Food Safety Authority

* non-compliance is given for different thresholds (EFSA proposed upper and lower thresholds for different categories of animals as listed in Table III)

** considering only consecutive periods of over 2 h with temperatures in excess of the limits proposed by EFSA

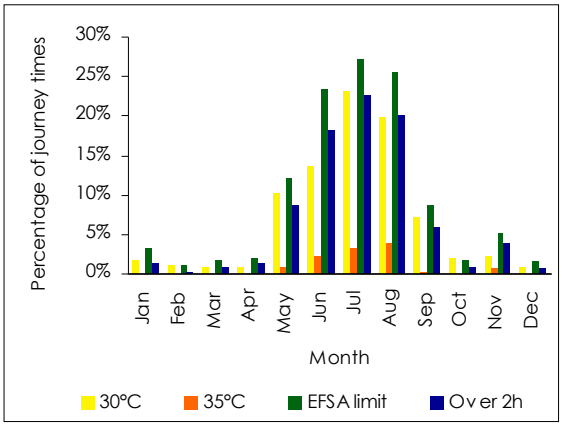

Figure 7
Percentage of journey times with temperatures inside the vehicle above the maximum temperature limits
Maximum temperature limits of 30°C (yellow) and 35°C (orange) proposed by EFSA (green) and considering only consecutive periods of over 2 h with excess temperature compared to the limits proposed by EFSA (blue)

When considering the number of non-compliant events by animal category (Fig. 8), the EFSA limits produced a larger increase in non-compliant occurrences with respect to journey times for pigs >30 kg and sheep >6 months compared to the 30°C limit. On the contrary, the higher EFSA limits resulted in less non-compliant occurrences in pigs up to 30 kg and sheep ≤6 months.

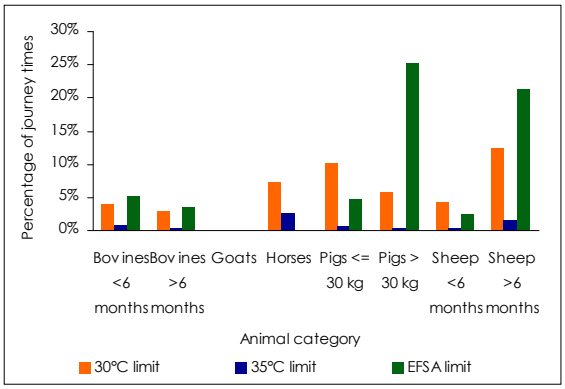

Figure 8
Percentage of journey times with temperature records inside vehicles exceeding the 30°C and 35°C limits and the limits proposed by the European Food Safety Authority (EFSA) during animal journeys, by category of animals transported

In addition to the absolute number of non-compliant events during animal journeys, their consecutive durations compared their average value were also analysed. Figure 9 shows, for all animal categories, the average temperature during consecutive periods with maximum temperatures on at least one of the internal sensors that exceeds the limit of 30°C versus the duration of each of these periods. Bar charts along the axis represent the frequency distributions of temperatures and durations in hours.

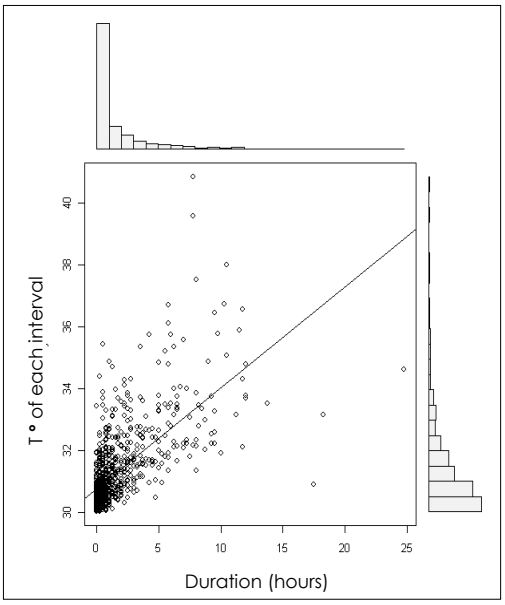

Figure 9
Plot of consecutive intervals during animal journeys with the maximum internal temperature above 30°C, with regression line
The x-axis shows the duration in hours of each interval and the y-axis the average temperature during each interval
Histograms along each axis show the frequency distributions of the number of intervals by duration and average temperature

The durations of consecutive periods with non-compliant temperatures were mostly under one hour. Of all 788 consecutive periods with temperatures above 30°C, 75% were less than 2 h and had a temperature of less than 32°C. In only 86 cases (11%) did they exceed 5 h.

Impact of low temperature thresholds

In 17% of journeys, for animal categories, there was at least one non-compliant incident against the 0°C limit. In 46% of the journeys there was at least one occurrence of a temperature that was below the 5°C limit and

in 58% cases below the proposed EFSA limits. The average numbers of occurrences outside the limits per journey were 21, 42 and 51, respectively.

During the journeys, again for all animal categories, the minimum temperatures inside the vehicles were below the limit of 0°C in 3% of the journey times, below 5°C in 18% and below the limits proposed by EFSA in 26% (calculated, as for the upper threshold). As shown in Figure 10, most non-compliant occurrences with respect to the journey times for low temperatures were recorded between November and March. In January, temperatures below the 5°C and the EFSA limits were recorded in 60% and 70% of the journey times, respectively.

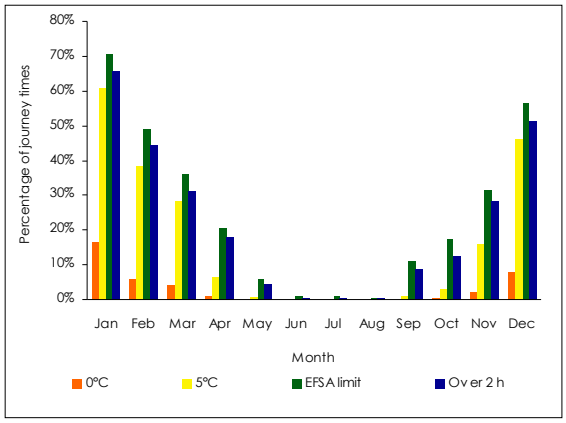

Figure 10
Percentage of journey times showing temperatures inside the vehicles below the minimum temperature limit of 0°C, 5°C, that proposed by the European Food Safety Authority (EFSA) and considering only consecutive periods of over 2 h with temperatures in excess of the limits proposed by EFSA

The higher EFSA limits for low temperatures resulted in more non-compliant occurrences than the 5°C limit, in particular for pigs, sheep up to 6 months and goats (Fig. 11). On the contrary, for bovines and sheep >6 months of age the EFSA limit resulted in a reduction of non-compliant occurrences compared to the 5°C limit.

The consecutive periods of temperatures below 5°C recorded by at least one of the

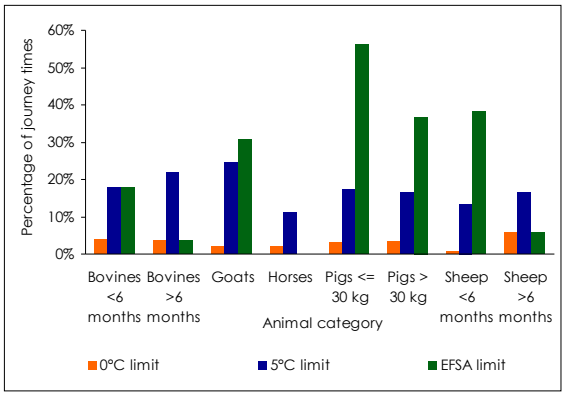

Figure 11
Percentage of journey times with temperatures inside vehicles below the limit of 0°C and 5°C and the limits proposed by the European Food Safety Authority (EFSA) during animal journeys by category of animals transported

internal sensors were mostly close to the threshold for durations below 3 h (Fig. 12). Of 1 279 recorded cases of temperatures that were below 5°C, 75% were less than 3.7 h and had temperatures that exceeded 2.6°C. In 248 cases (19%), the consecutive duration of occurrences exceeded 5 h.

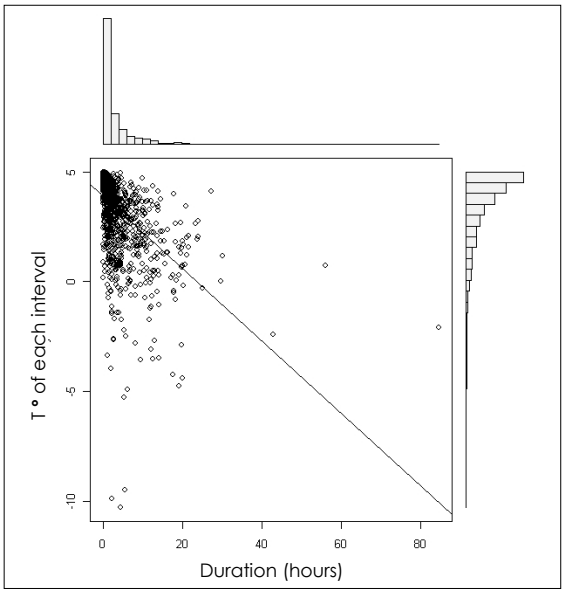

Figure 12
Plot of consecutive intervals during animal journeys with the minimum internal temperature below 5°C, with regression line
The x-axis shows the duration in hours of each interval and the y-axis the average temperature during each interval
Histograms along each axis show the frequency distributions of the number of intervals by duration and average temperature

Combined impact of temperature and humidity

To consider the combined effect of temperature and humidity, a temperature humidity index (THI) introduced by Thom as a discomfort index in humans (15) was calculated according to the following formula:

THI = 0.8 T + RH (T-14.4) + 46.4

where

T = temperature recorded by the sensor (°C) and RH = relative humidity (%).

The THI values were compared with the thresholds used by the livestock weather safety index (LWSI). The LWSI, which was developed and mainly used for the evaluation of productivity decrease in bovines (4, 5), provides a limit of 74 for the THI for the onset of thermoregulatory mechanisms by the animals, a danger zone with values between 78 and 84 and an emergency zone with values above 84 when lasting over prolonged periods of days.

A total of 83% of the values recorded by the front lower sensors during animal journeys had a THI below 74, 10.5% between 74 and 78, 6% between 78 and 84, and 0.5% above 84.

The durations of the consecutive periods of times with a THI above 74 were mostly limited to few hours as shown in Figure 13. Of all 1 785 cases of animal journeys in which temperature and relative humidity resulted in a THI value that exceeded 74, 112 cases (6%) indicated that the elevated THI was present for more than 10 h.

Discussion

Although our study gives a realistic picture of temperatures that occur in commercial livestock transport in Europe, it cannot be considered to be representative of all transport conditions which might be experienced along the main routes, given the fact that these conditions are influenced by a complex interaction of seasonality, timing and geographic distribution of the journeys.

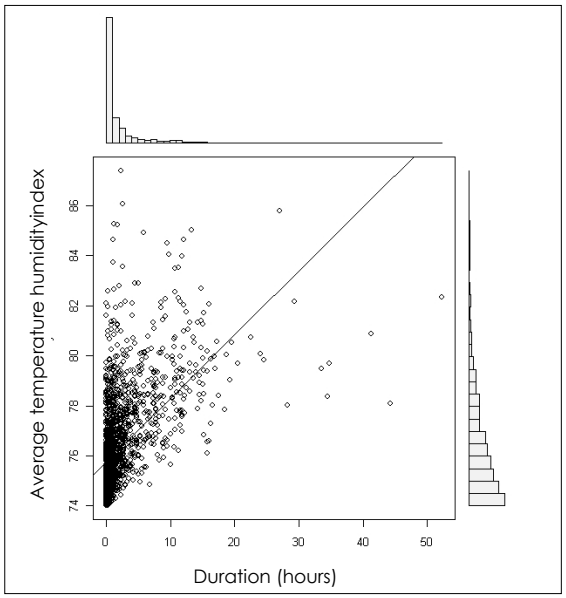

Figure 13
Plot of consecutive intervals during animal journeys with the temperature humidity index (THI) above 74, with regression line
The x-axis shows the duration in hours of each interval and the y-axis the average THI during each interval Histograms along each axis show the frequency distributions of the number of intervals by duration and average THI

Temperatures and sensor locations

All records, including the phases when animals were on board, revealed that the sensors in the upper part of the vehicle showed a wide variation between day and night compared to the external sensor and in the lower part of the animal compartments. The higher temperatures during the day in the upper part of the vehicles could be attributed to a large extent to solar radiation, whereas the lower than external temperatures might have been due to the fact that the vehicles could be losing radiant heat at night. This effect is less clear during journey times due to the ventilation produced by the movement of the vehicles.

The differences observed during the movement of the vehicles between the front sensor and the back sensor in the upper part of the vehicles can be explained by lower pressure behind the vehicle which was generated by the movement of the vehicle which sucks air from outside into the back of the animal compartments.

The fact that on average the lower part of the compartments has temperatures that are below those recorded outside indicates an effect of insulation of the vehicle against higher external temperatures.

The effects described on the inside temperatures indicate that the location of the worst climatic conditions within the animal compartment change due to a number of factors (e.g. if low or high temperatures are considered, time of the day, external temperature, presence of the animals).

In general, there is a strong correlation between the four sensors in a mono-volume vehicle with only one tier as used for example in the transportation of horses. In multi-tier vehicles, a strong correlation is observed between the sensors on the same tier, but much less is seen between sensors in the upper and lower tiers. Correlation of temperatures in a truck and its trailer was weaker than within the semi-trailer. These findings indicate the importance of the position of temperature sensors. Only with a positioning of sensors based on objective criteria would it be possible to have a good representation of the temperature conditions which are present in the different parts of the vehicle and to compare the data from different vehicles.

Presence of animals

The increased temperatures in the front lower part of vehicles, linked to the presence of animals, could be caused by lower ventilation in that area compared to the back and upper parts.

The finding that the animals were not contributing much to the internal temperature when external temperatures exceeded 20°C may be due to the fact that in warm conditions, animals have more problems to transfer heat to their surrounding. The highest increase in temperature observed in the front lower part of the vehicles with pigs up to 30 kg body weight may be explained by the higher loading density and/or higher caloric transmission of the piglets to their surroundings.

With regard to the number of animals loaded, information was obtained for each journey. However, without more precise information on how the load was distributed within the vehicles, a correlation between loading density and temperatures measured in the different parts of the vehicle could not be established.

Variation of relative humidity

The negative correlation between temperature and humidity shows that under climatic conditions in which the journeys were made, there were only few cases with high temperature and high relative humidity and that these few cases were limited in duration. The decrease in humidity observed during animal journeys can be explained by higher ventilation during movement of the vehicle.

Temperatures recorded in relation to thresholds

The overall picture regarding temperatures recorded above the upper and below the lower threshold shows a large number of animal journeys with at least one non-compliant temperature record. The temperature thresholds proposed in the EFSA opinion would result in a higher percentage of non-compliant conditions, which was more prominent at the lower temperature threshold.

When analysing the temperature data for all animal journeys in regard to the consecutive duration and the out-of-range values, it can be shown for both the upper and lower thresholds that the vast majority of non-compliant temperatures recorded against the thresholds in Regulation (EC) 1/2005 last less than 2 h during the journey with average temperatures of just 1°C-2°C over the threshold. According to our findings, we believe that it is not fully appropriate to take into account the temperature values only, but this must be considered with the duration of the out-of-range values (for instance, non-compliant temperature values lasting for 2 h or 3 h, rather than single events) and the THI values.

When non-compliant events for a consecutive period of less than 2 h are excluded, the percentage of non-compliant journeys against EFSA thresholds would decrease from 40% to 17% for the upper limits and from 58% to 44% for the lower limits.

With respect to the 30°C threshold, the out-of-range temperatures were more frequent in pigs weighing up to 30 kg and in sheep >6 months of age and could be linked to a higher loading density and/or higher heat transmission of the piglets to their surroundings and to the fact that most sheep journeys were recorded during the summer.

Setting the upper thresholds at a lower level as proposed by EFSA would cause a sharp increase in non-compliant journey times for pigs >30 kg body weight from approximately 6% to 25% and in sheep >6 months of age from 13% to 21% when compared with 30°C. For cattle, the thresholds proposed by EFSA would be different only at a humidity level that exceeded 80%; this did not occur frequently in the period recorded. Indeed, the percentage of non-compliance would not change much compared to the 30°C threshold.

With the higher temperatures proposed for the lower threshold by EFSA, the times of out-of-range temperatures would increase substantially for pigs weighing up to and above 30 kg and in sheep aged ≤6 months. In pigs ≤30 kg the non-compliant times would increase from below 20% to over 55%, in pigs >30 kg from approximately 18% to 36%, in sheep ≤6 months from 12% to nearly 40% when compared with 5°C. Changing the lower threshold from 5°C to 0°C in cattle over 6 months of age, out-of range temperatures would fall from approximately 10% to approximately 2% (Figs 8 and 11).

The values of non-compliance in goats with respect to the lower threshold should be read with caution due to the very few journeys recorded for this species.

Temperature humidity index

When analysing THI values exceeding 74 in regard to their consecutive duration, it can be observed that only in few cases did a high THI last for more than 10 h. In cattle, for values exceeding 75, stress-limiting measures, such as increased ventilation, should be considered. Values exceeding 79 are considered to be dangerous for cattle if exposed to these values over days with insufficient adaptation time (5, 10). While thresholds for the THI have been established for cattle, very little information is available for other species in respect to acceptable THI values and duration.

Impact on the trade flows

Given the main flows of livestock between northern and eastern areas of Europe on the one hand and middle and southern Europe on the other, both the upper and the lower temperature limits are of concern for trade.

Regarding seasonal distribution, April, May, September and October showed less than 10% of non-compliant journeys against the thresholds of 5°C and 30°C. When applying a tolerance of ±5°C to the thresholds in August and December, approximately 5% and in January approximately 18% of journey times were not compliant. During the rest of the year, less than 5% of journey times were not compliant.

Applying the limits proposed by EFSA, 20% or less of journey times would be non-compliant under the present transport conditions in April, May, September and October.

Applying the limits proposed by EFSA, pigs ≤30 kg, sheep ≤6 months of age and pigs >30 kg showed the highest levels of non-compliance in journey times in respect to the lower thresholds (between 35% and 55% of non-compliant journey times). For the upper EFSA thresholds, between 20% and 25% of journey times for sheep >6 months of age and pigs >30 kg would be non-compliant.

As a consequence, under the proposed EFSA thresholds, the transportation of pigs >30 kg could result in a high rate of non-compliant journeys throughout the year in present transport conditions. The study indicates that for pigs ≤30 kg, sheep ≤6 months of age and probably goats, journeys between April and October showed a reduced risk of high non-compliance rates against EFSA thresholds. In contrast, for sheep >6 months of age, journeys could result in a high non-compliance rate between May and September. For cattle, the EFSA limits would increase non-compliant occurrences less significantly.

The impact of the EFSA limits on trade along specific routes cannot be specified. When studying each category of animals on selected

routes, the number of recorded journeys is relatively small and the conditions recorded may not be statistically representative for all transporters and climatic conditions along the trade flows. Transporters may also take additional precautions during the planning and execution of journeys to reduce the risk of exceeding temperature thresholds by improving transport conditions, such as increased ventilation when internal temperatures exceed 20°C (2, 3).

Conclusions

Using temperatures recorded during animal journeys to enforce legal temperature requirements, the number and position of sensors must be based on objective criteria to provide a good representation of the temperatures in the different parts of the vehicle and to obtain comparable results from different vehicles.

With outside temperatures of up to 20°C, temperature increases in the front lower area of vehicles can be used to indicate the presence of animals in the vehicle.

Although there will be journey types and conditions which were not covered in the study, our survey clearly indicated that the temperature thresholds proposed by the EFSA would result in a higher percentage of non-compliant conditions, in particular for the transportation of pigs that are below 30 kg live weight and for sheep that are over six months of age in respect to the high temperature threshold and of pigs of both weight groups and sheep below six months of age for the low temperature thresholds. In regard to the practical implementation of Regulation 1/2005, it would be useful to further investigate the relevance of temperatures beyond the thresholds stipulated with respect to welfare, in particular how to assess the impact of values beyond the thresholds in relation to duration.

Our study places emphasis on providing a realistic picture of the situation in commercial animal transport. However, we did not have full access to information on ventilation regimes and possibly other measures taken during the animal journeys to improve animal welfare conditions. Therefore, no conclusions can be drawn on the impact of those systems (i.e. mechanical ventilation and other possible measures) to alter temperatures (such as sprinklers) or on the temperatures recorded or their effectiveness to control acceptable temperature ranges.

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