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MAINTAINING THE PRE-SLAUGHTER ENTHALPY CHAIN IMPROVES ANIMAL WELFARE IN PIGS

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ABSTRACT High environmental temperatures affect animal welfare during transport, however, less is known about the role of humidity in influencing the degree of thermal stress imposed or the effects on integrated indices of thermal stress such as enthalpy. In this study temperature and humidity sensors were installed on commercial vehicles on seven long-distance (70 hours) livestock transport journeys that carried pigs from Scotland to Spain. Psychometric charts indicated an approximate overlap in air enthalpy (kg water/kg dry air) at the farm, during transport and at the abattoir, while the relative changes in temperature (ºC/second) and humidity (%RH/second) were much higher during transport and appeared to impose more stress upon the pigs (evaluated as the amount of time they spent resting or drinking post-transport). Thus, relative changes in enthalpy can be used as a non-invasive welfare indicator during transport and appears to be more useful than absolute values of temperature or relative humidity.

Keywords: Pig, Enthalpy, Stress, Welfare, Indicator, Non-invasive.

INTRODUCTION. Environmental temperature and relative humidity affect animal production (Whittemore & Kyriazakis, 2006), but little has been described about the effect of relative changes in enthalpy on pig welfare (Daskalov et al., 2006). According to European Union Council Regulation EC 1/2005, pigs in transport should not be subjected to temperatures above 30ºC, and never above 35ºC. The thermal comfort zone, under production conditions, for 100 kg pigs is estimated to be 20±2ºC (Whittemore & Kyriazakis, 2006). However, little attention has been given to humidity values, which may vary greatly in production and transportation environments, thus having important direct effects upon the total thermal loads imposed upon animals, and which may be expressed as enthalpy or the apparent temperature perceived by the animals (Barbosa et al., 2008).

Enthalpy is the heat energy of the air surrounding the animal and dictates the degree of heat loss to the environment (Moura 1997; Fihlo et al 2005, 2008). According to the temperature humidity index (THI), pigs are most comfortable at a THI lower than 75 (using ºC, Lucas et al., 2000). However, little is known about relative changes of enthalpy on the farm, and how they may change during transport and at the abattoir. Abrupt changes in the enthalpy conditions or pre-slaughter enthalpy chain, may have direct and more serious effects on welfare than degree differences in temperature alone.

In this study, temperature and humidity sensors were placed on a livestock transport vehicle that carried groups of 80 pigs on seven long distance journeys (approximately 70 hours duration) under summer conditions, from Scotland to Spain. The relative changes in temperature and relative humidity were calculated and related to pig stress assessed by pig behaviour after unloading.

MATERIALS AND METHODS

Journeys. Seven journeys were made from Scotland to Malaga (Spain) between May and October 2008 with a commercial livestock transport vehicle carrying 90 pigs each trip. All pigs were loaded in Edinburgh, taken to Fougeres (France), crossing the English Channel by ferry, where they were unloaded for 24 hours, and reloaded and moved to Humilladero, Malaga (Spain). The total journey time, including the 24 hour rest period in the French control post, was approximately 70 hours.

Sensors. Temperature and humidity sensors were placed on the farm where animals were loaded, on the livestock transport vehicle (inside and outside the vehicle) during transport and at the abattoir. The sensors on the farm were placed in two pens near the experimental animals and recorded once every 30 min from May to October. Two more sensors were placed inside the lairage pens and also recorded once every 30 min from May to October. Two more sensors were placed outside the abattoir to measure to local conditions at the end of the journeys, also at 30 min. The sensors on the truck were fitted and removed before and after each trial. All sensors were set to record temperature once every two minutes.

Data handling. The psychometric charts produced using the data collected from the sensors were computed based on the ASABE model which includes temperature, relative humidity, absolute humidity and enthalpy. The Psychrometric data ASAE D271.2, defined in April 1979 and reviewed in 2005 (ASABE 2006 St. Joseph, MI) were used to calculate the psychrometric properties of the air at farm, during transport (both outside and inside the vehicle) and at the abattoir.

The temperature derivative was computed using the Savitzky-Golay algorithm to smooth one-dimensional, tabulated data and compute the numerical derivatives using the Savgol routine in Matlab. Thus, a polynomial was used to fit the data surrounding each data point. The smoothed points were computed by replacing each data point with the value of its fitted polynomial. Numerical derivatives arose after computing the derivative of each fitted polynomial at each data point. In our case a window of 21 points was used with a five order polynomial.

The phase space for temperature is used in this study. In mathematics and physics, a phase space, introduced by Willard Gibbs in 1901, is a space in which all possible states of a system are represented with each possible state of the system corresponding to one unique point in the phase space. For simple systems, such as a single particle moving in one dimension for example, there may be as few as two degrees of freedom, (typically, position and velocity), and a sketch of the phase portrait may give qualitative information about the dynamics of the system. In our case, this has been applied for temperature and its corresponding gradient (dT/dt). The observation of the ranges of variation in the phase space for environmental allowed the definition of certain thresholds which have afterwards been used to compute thermal integrals along the shipments.

Animals. All pigs (gilts) were reared in pens in stable groups of ten and were fed commercial rations and were prepared for transport at a body weight of approximately 100kgs. Pigs were weighed at loading on to the vehicle immediately prior to transportation and again at unloading upon arrival in Spain. Analysis of the behaviour of the pigs was also performed after shipment with regard to their activity level, standing, lying and drinking. The time budgets for each activity were determined during a three hour period immediately after transportation for 2 groups of 10 pigs.

RESULTS

Table 1. Summary of the seven journeys between Scotland and Spain, including loading date (L_{date}), average temperature throughout the journey (T_{avg}), maximum temperature (T_{max}), minimum temperature (T_{min}), average relative humidity throughout the journey (RH_{avg}), maximum relative humidity (RH_{max}) and minimum relative himidity (RH_{min}) as well as the number of sensors on the vehicle ($N_{sensors}$)

Trip	L_{date}	T_{max}	T_{avg}	T_{min}	RH_{max}	RH_{avg}	RH_{min}	$N_{sensors}$
1	04/06	28.11	18.23	10.20	90.43	58.90	23.65	4
2	09/07	29.80	20.37	13.78	91.20	66.00	29.68	4
3	23/07	40.64	22.97	16.19	84.50	58.79	23.90	4
4	06/08	35.29	21.84	15.04	90.50	63.84	23.55	4
5	20/08	32.86	20.16	12.55	92.10	65.49	23.60	4
6	18/09	31.83	16.90	7.43	86.65	59.58	28.53	4
7	15/10	24.52	15.11	5.02	94.82	65.62	36.67	10

Journeys and experimental animals. All seven journeys were completed with no injuries to the pigs or mortalities, between June and October 2008. The average journey length, including the rest period at Fougeres, was 63.3 hours. In journeys 6 and 7, slightly less than 80 pigs were loaded since 3 and 1 pigs, respectively, were deemed unfit for transport (pre-loading). Average temperatures were highest during journeys 3 and 5, while average relative humidity was higher in journey 4 (Table 1).

Temperature, humidity and enthalpy. Since temperature and humidity values were taken every 2 minutes during transport, we obtained a total of 1900 data points (over 63.3 hours). The changes in temperature with time throughout are shown in Figure 1 for journey 3, under some of the hottest conditions.

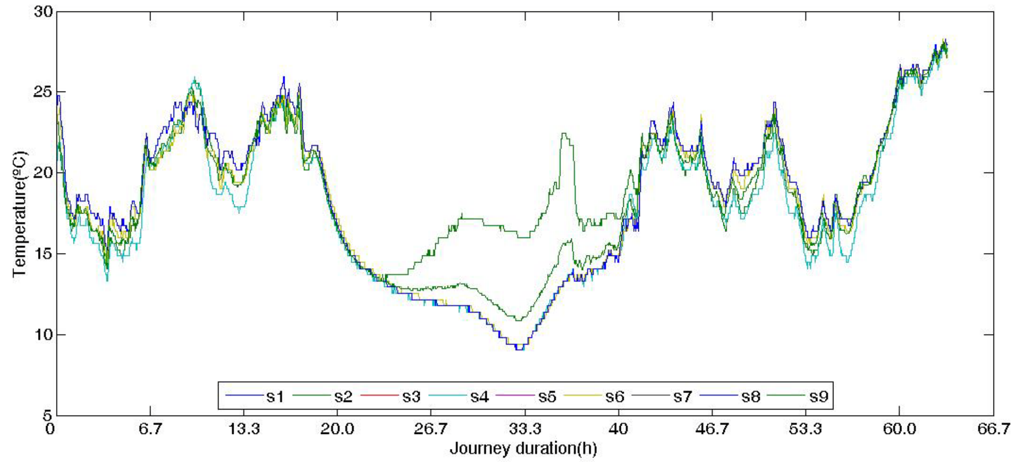
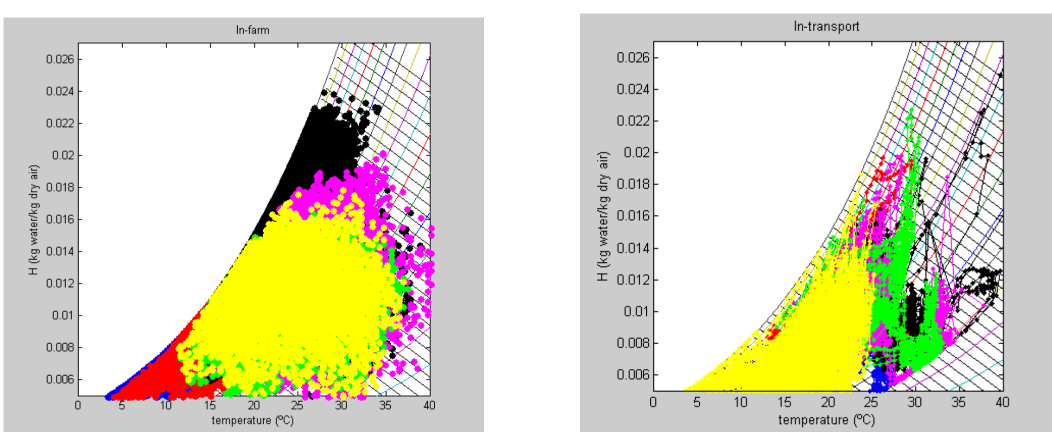


Figure 1. Changes in temperature throughout long distance journey 3, during some of the hottest weather. Temperature decreased on the vehicle after pigs were off-loaded 22 hours after loading, at a staging/resting post, where they were kept for 24 hours before resuming the journey.

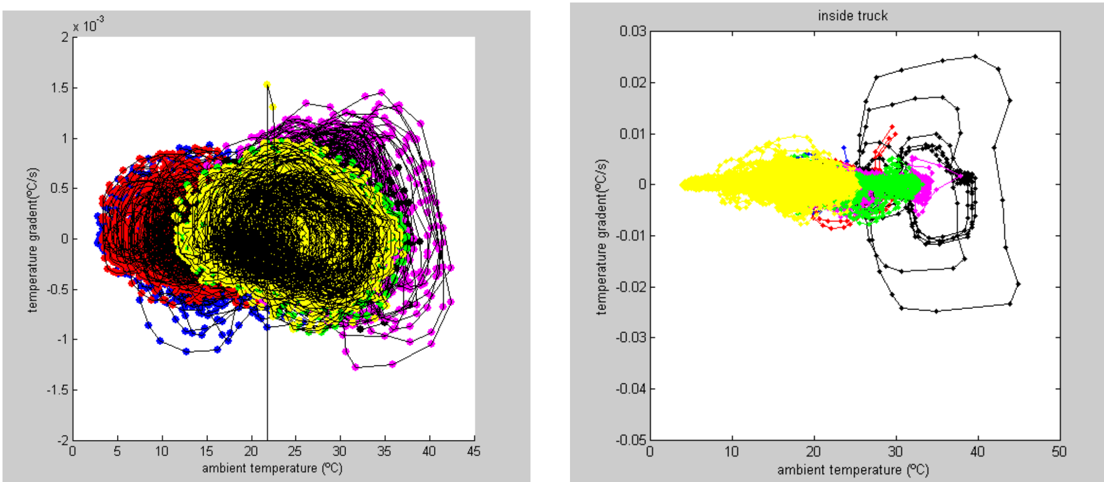
According to the psychometric charts obtained, the enthalpy of the air surrounding the pigs at the farm in Scotland, during transport to Spain and at the abattoir largely overlapped (Figure 2). Although temperatures were slightly lower in Edinburgh and higher in Malaga, the average enthalpy values ranged between 0.005 and 0.02 kg water/kg dry air.



(a) (b)

Figure 2. Psychometric charts on a) farm, and b) during transport inside the livestock vehicle. The relative phase space of enthalpy values during transport overlaps with those normally experienced by the pigs on the farm.

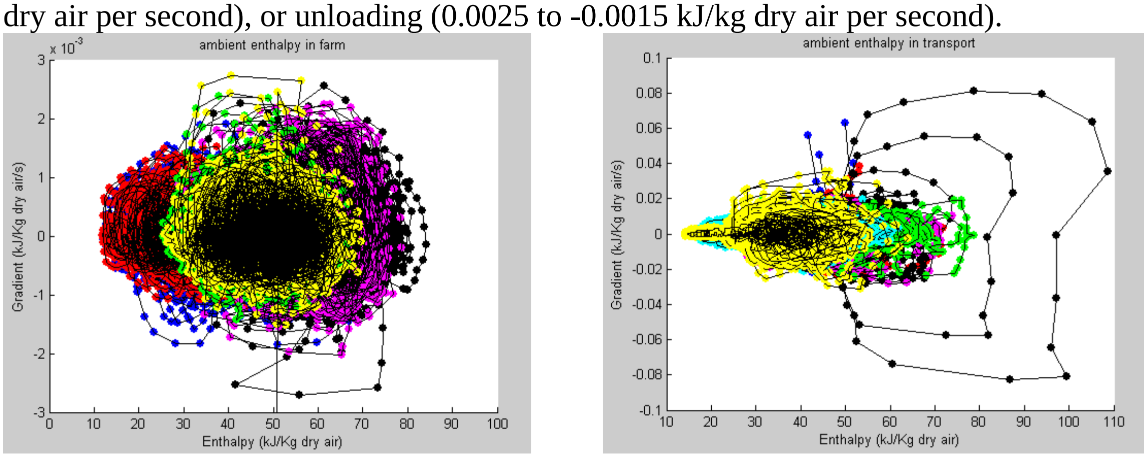
However, the gradient of change in temperature was much higher during transport than at the loading or unloading sites (Figure 3). The change in ambient temperature during transport varied between -0.025 and 0.025 ºC/s, 10 times higher than the range of changes at the farm (0.8 and -1.0 ºC/s) or abattoir, (0.8 to -0.8 ºC/s).



(a) (b)

Figure 3. Summary of the speed of change in temperature (with respect to previous value) on farm (a) and during transport (b). Note that the y-axis values are 10 times higher during transport, indicating that the speed of change in temperature during transport is 10 times higher than on the farm.

Similarly, the gradient in change of enthalpy (Figure 4) was much higher during transport, (0.08 to -0.08 kJ/kg dry air per second), than at loading (0.002 to -0.002 kJ/kg dry air per second), or unloading (0.0025 to -0.0015 kJ/kg dry air per second).



(a) (b)

Figure 4. Summary of the speed of change in enthalpy (with respect to its previous value) on farm (a) and during transport (b). Note that the y-axis values are 10 times higher during transport, indicating that the speed of change in temperature during transport is 10 times higher than on the farm.

Behaviour analysis. After unloading, pigs from journey 3 spent significantly more time drinking than pigs in the other journeys (Figure 5), while after most other journeys the pigs spent more time resting.

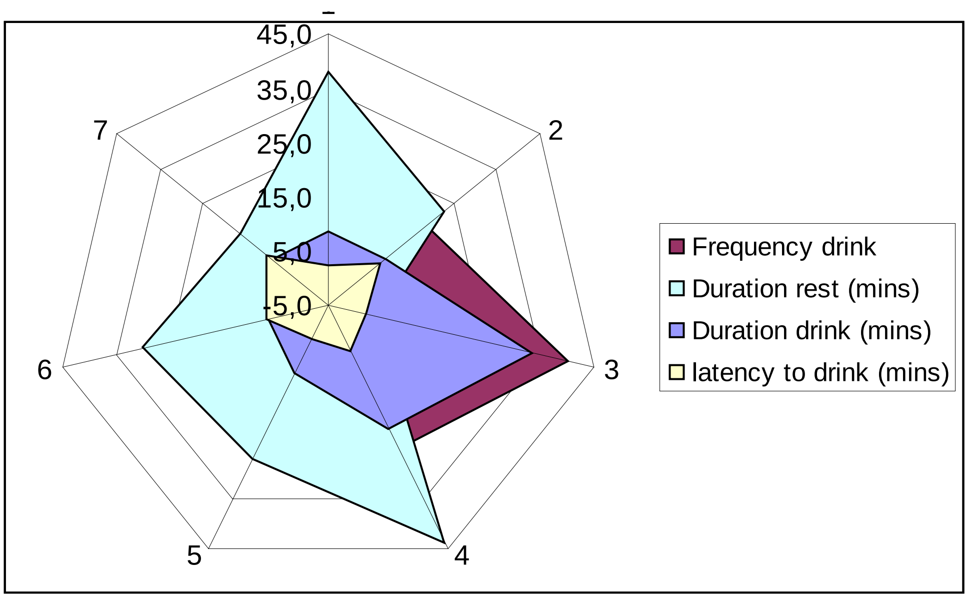


Figure 5. Behaviour of pigs after transport in terms of frequency of drinking, duration of resting, duration of drinking and latency to drink (see definitions in methods).

DISCUSSION

The data in this study suggest that the gradient in temperature and enthalpy values during transport provides a sensitive non-invasive indicator of animal welfare. According to the psychometric charts, air enthalpy did not vary widely at the loading or unloading sites or during transport, indicating that temperature or relative humidity alone do not provide a robust indicator of environmental stress.

Although it is well known that air enthalpy affects animal production (Whittemore & Kyriazakis, 2006), less is known about how enthalpy changes during transport. In our study, an exhaustive analysis of temperature and relative humidity on seven journeys (13300 data points in total), suggests that both temperature and humidity vary as much as 10 times more during transport compared to the conditions that pigs are used to on the farm or that they undergo at the abattoir. In addition, when more relative change is experienced by the pigs, they spend more time drinking after transport, indicating that those conditions are more stressful.

Major consequences of exposure to elevated thermal loads in transit may be dehydration and fatigue. Whilst these effects are difficult to measure directly in the animals during the journey, particularly if the effects are marginal, they can be assessed post-transport by examining behaviour. Thus the degree of dehydration may be reflected by the motivation to drink and thus the frequency and duration of drinking and fatigue may be indicated by the time allocated to resting. In animals experiencing both thirst and fatigue, there may be a behavioural "trade-off" allowing the animals to satisfy both their physiological requirements and motivations to the appropriate extent. Differences in these behaviours between journeys and transport environments may be correlated with the thermal loads imposed during the journeys when expressed as an integrated index such as enthalpy"

Overall, our data agree with the conclusions of the EU Council Regulation 1/2005 (European Commission, 2004), since the pigs that spent more time above 30ºC appeared to be more stressed.

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